PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

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FOR THE YEAR MDCCCXLV.

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PART I.

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MDCCCXLV.

ADVERTISEMENT.

THE Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the Council-books and Journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries till the Forty-seventh Volume; the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March 1752. And the grounds of their choice are, and will continue to be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgement of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body,

27718

upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report and even to certify in the public newspapers, that they have met with the highest applause and approbation. And therefore it is hoped that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

The Meteorological Journal hitherto kept by the Assistant Secretary at the Apartments of the Royal Society, by order of the President and Council, and published in the Philosophical Transactions, has been discontinued. The Government, on the recommendation of the President and Council, has established at the Royal Observatory at Greenwich, under the superintendence of the Astronomer Royal, a Magnetical and Meteorological Observatory, where observations are made on an extended scale, which are regularly published. These, which correspond with the grand scheme of observations now carrying out in different parts of the globe, supersede the necessity of a continuance of the observations made at the Apartments of the Royal Society, which could not be rendered so perfect as was desirable, on account of the imperfections of the locality and the multiplied duties of the observer.

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ROYAL MEDALS.

HER MAJESTY QUEEN VICTORIA, in restoring the Foundation of the Royal Medals, has been graciously pleased to approve the following regulations for the award of them:

That the Royal Medals be given for such papers only as have been presented to the Royal Society, and inserted in their Transactions.

That the triennial Cycle of subjects be the same as that hitherto in operation: viz.

1. Astronomy; Physiology, including the Natural History of Organized Beings.
2. Physics; Geology or Mineralogy.
3. Mathematics; Chemistry.

That, in case no paper, coming within these stipulations, should be considered deserving of the Royal Medal, in any given year, the Council have the power of awarding such Medal to the author of any other paper on either of the several subjects forming the Cycle, that may have been presented to the Society and inserted in their Transactions; preference being given to the subjects of the year immediately preceding: the award being, in such case, subject to the approbation of Her Majesty.

The Council propose to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Astronomy, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

The Council propose also to give one of the Royal Medals in the year 1845 for the most important unpublished paper in Physiology, including the Natural History of

Organized Beings, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1842, and prior to the termination of the Session in June 1845.

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The Council propose also to give one of the Royal Medals in the year 1848 for the most important unpublished paper in Physiology, including the Natural History of Organized Beings, communicated to the Royal Society for insertion in their Transactions after the termination of the Session in June 1845, and prior to the termination of the Session in June 1848.

CONTENTS.

I. *On the Laws of the Tides on the Coasts of Ireland, as inferred from an extensive series of observations made in connection with the Ordnance Survey of Ireland.* By G. B. Airy, *Esq., F.R.S., Astronomer Royal.* . . . . . page 1

II. *On the Temperature of the Springs, Wells and Rivers of India and Egypt, and of the Sea and Table-lands within the Tropics.* By Captain Newbold, *Madras Army, F.R.S.* 125

III. *An Account of* Newton's *Dial presented to the Royal Society by the Rev.* Charles Turnor, *in a letter addressed to the* Marquis of Northampton, *Pres. R.S., &c. By the Rev.* Charles Turnor, *F.R.S. Communicated by the President.* 141

IV. Ἀμόρφωτα, No. I.—*On a Case of Superficial Colour presented by a homogeneous liquid internally colourless.* By Sir John Frederick William Herschel, *Bart., K.H., F.R.S., &c. &c.* 143

V. Ἀμόρφωτα, No. II.—*On the Epipolic Dispersion of Light, being a Supplement to a paper entitled, "On a Case of Superficial Colour presented by a homogeneous liquid internally colourless."* By Sir John Frederick William Herschel, *Bart., K.H., F.R.S., &c.* 147

VI. *On the Liquefaction and Solidification of Bodies generally existing as Gases.* By Michael Faraday, *Esq., D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Corr. Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, &c. &c.* 155

PHILOSOPHICAL TRANSACTIONS.

I. *On the Laws of the Tides on the Coasts of Ireland, as inferred from an extensive series of observations made in connection with the Ordnance Survey of Ireland.* *By* G. B. Airy, *Esq., F.R.S., Astronomer Royal.*

Received November 30, 1844,—Read December 12, 1844.

In the spring of 1842 I was informed by Colonel Colby, R.E., Director of the Trigonometrical Survey, that in the operations of the Survey of Ireland it had become necessary to adopt a line of reference for the elevations ascertained in the running of various lines of level through the country; and that it was his intention to institute a series of observations of the height of the water in different states of the tide, in order to refer the levels to the mean height of the sea, or to its height at some definite phase of the tide. Colonel Colby stated also that he was desirous that the observations should be made subservient to improvements in the theory of the tides, and requested my assistance in sketching a plan of observation which would be most likely to contribute to that end.

In reply, I made the following suggestions:—That great care should be taken in the accurate determination of time at every station, and that for this purpose the non-commissioned officer of the Royal Sappers and Miners who had the care of the observations at each station, should be entrusted with a pocket chronometer, and that an officer should, at least twice during the series of observations, visit every station, carrying, for comparison, an itinerant chronometer whose error on Greenwich time was accurately known from astronomical observations. That stations should be chosen on the eastern as well as on the western coast, in order to determine the difference of level, if any, between an open sea and a partially inclosed sea. That on the north-eastern coast, stations should be selected at smaller intermediate distances than at other parts of the coast, with the purpose of removing, if possible, the doubt which appears to exist as to the progress of the semidiurnal tide-wave through the North Channel. That, where practicable, several stations should be selected on each of the large rivers or estuaries, in order to ascertain the nature of the modification

which the tide-wave undergoes in passing up a contracted channel of comparatively small depth. That the series of observations should be so arranged, that, at every station, one complete tide (from high water to high water, or from low water to low water) should be completely observed on every day, its observations being made at small equidistant intervals. That supplementary observations, applying only to the neighbourhood of the low water or high water omitted in the observations of the complete tide, should also be made, for the development of the principal facts of diurnal tide. Finally, that the zeros of the tide-gauges should be connected with the principal lines of level, so that every observation should be referred to the same hydrostatic level.

These suggestions were adopted in their utmost extent by Colonel Colby. The collection of observations was placed in my hands in the winter of 1842. The whole number of observations exceeds two hundred thousand; the circumstances of place, simultaneity, extent of plan, and uniformity of plan, appear to give them extraordinary value; and extent of time alone appears wanting to render them the most important series of tide-observations that has ever been made.

Having under my immediate direction a large number of computers, employed at the Royal Observatory under the authority of the Lords Commissioners of the Treasury for the reduction of the Greenwich Lunar Observations, I requested the sanction of their Lordships for the employment of a part of this force on the reduction of these tide observations. With this request their Lordships were pleased to comply; and the investigations and results which I have now the honour to lay before the Royal Society are the fruit of this liberality.

The following is the order in which I propose to arrange the parts of this memoir:—

Section I.—Account of the stations, levellings, times, and methods of observation.

Section II.—Methods of extracting from the observations the times of high and low water; of supplying deficient times and heights; and of correcting the times first determined.

Section III.—Theory of diurnal tide as related to observations only; and deduction of the principal results for diurnal tide given immediately by these observations.

Section IV.—Theory of diurnal tide as referred to the actions of the sun and moon.

Section V.—Discussion of the height of apparent mean water, as deduced from the heights of high and low water only, corrected for diurnal tide; with reference to difference of station, and to variations of the phase of the moon, and of the declination of the moon.

Section VI.—Discussion of the range of the tide, and of semimenstrual inequality in height, apparent proportion of solar and lunar effects as shown by heights, and age of tide as shown by heights; from high water and from low water.

Section VII.—Establishment of each port, and progress of semidiurnal tide round the island.

Section VIII.—Semimenstrual inequality in time; proportion of solar and lunar

effects as shown by times, and apparent age of tide as shown by times; from high water and from low water.

Section IX.—Formation of the time of diurnal high water; progress of the diurnal tide-wave round the island; comparison of its progress and range with those of the semidiurnal tide.

Section X.—Method of expressing the height of the water, throughout every individual tide, by sines and cosines of arcs; and expressions in this form for every tide in the whole series of observations, except those at Courtown.

Section XI.—Discussion of the height of mean water deduced from the analysis of individual tides; with reference to difference of station, and to variations of the phase of the moon, and of the declination of the moon.

Section XII.—Discussion of range of tide, or coefficient of first arc in the analysis of individual tides; and of semimenstrual inequality in range, apparent proportion of solar and lunar effects, and age of tide as deduced from range.

Section XIII.—Establishment of each port, as deduced from the time of maximum of the first periodical term in the analysis of individual tides.

Section XIV.—Semimenstrual inequality in time, proportion of solar and lunar effects from times, and apparent age of tide as shown by times; deduced from the time of maximum of the first periodical term.

Section XV.—Comparison of the results as to mean height, range, semimenstrual inequality in height, age of tide obtained from height, establishment, semimenstrual inequality in time, and age of tide obtained from time, deduced from high and low waters only, in Sections V., VI., VII., VIII., with those deduced from the analysis of individual tides in Sections XI., XII., XIII., XIV.

Section XVI.—Remarks on the succeeding terms of the expressions for individual tides, as related to the magnitude of the tide, to the position on the sea-coast, to the position on the river, &c.; comparison with the terms given by the theory of waves; discussion of the quarto-diurnal tide.

Section XVII.—Separate discussion of the tidal observations at Courtown.

Section XVIII.—Examination into the question of tertio-diurnal tide.

Section I.—*Account of the Stations, Levellings, Times, and Methods of Observation.*

The following are the stations of observation:—

1. Kilbaha.—A small bay in the Shannon, on its north side, very near to the Loop Head; latitude 52° 34′, longitude 9° 52′ west of Greenwich. The gauge was a graduated post erected in the sea at a short distance from the pier; it was kept upright by large stones at its base, and by guys with large stones lashed to them.

2. Kilrush.—A small town on the north bank of the Shannon, about sixteen miles above Kilbaha; latitude 52° 38′, longitude 9° 29′. The gauge was a graduated scale nailed to the Revenue Pier.

3. Foynes Island.—An island in the Shannon, about fifteen miles above Kilrush; latitude 52° 37′, longitude 9° 9′. The gauge was a pole in the narrow channel on the south side of the island.

4. Limerick.—The tide-gauge was on the face of Mead's Quay, the lowest (on the course of the river) of the quays at Limerick; latitude 52° 39′, longitude 8° 39′.

5. Casleh Bay.—A small bay in the north side of Galway Bay, near its entrance; latitude 53° 14′, longitude 9° 34′. The tide-gauge was a pole in the water near the Coast-Guard Station.

6. Galway.—The tide-gauge was nailed to the pier, at the entrance to the New Dock; latitude 53° 17′, longitude 9° 2′.

7. Old Head.—A station on the south side of Clew Bay; latitude 53° 47′, longitude 9° 47′. The gauge was at first nailed to a small quay; it was afterwards fixed in the water.

8. Mullaghmore.—A station on the south side of Donegal Bay; latitude 54° 27′, longitude 8° 26′. The gauge was nailed to the south pier of a small port called Classybaun Harbour.

9. Buncrana.—A station on the east side of Lough Swilly, about ten miles from its mouth; latitude 55° 8′, longitude 7° 27′. The gauge was fixed in the water, opposite to a fortress called Ned's Point Battery.

10. Port Rush.—A small harbour near the entrance of Lough Foyle; latitude 55° 11′, longitude 6° 40′. The gauge was nailed to the northern pier.

11. Carrowkeel.—A station on the western side of Lough Foyle, about twelve miles from its mouth; latitude 55° 7′, longitude 7° 11′. The gauge was nailed to a large post permanently fixed in the water.

12. Ballycastle.—A small port opposite Rathlin Island; latitude 55° 12′, longitude 6° 14′. The gauge was a pole in the water.

13. Glenarm.—A small port between Ballycastle and Belfast; latitude 54° 56′, longitude 5° 56′. The gauge was nailed to the pier.

14. Donaghadee.—Latitude 54° 39′, longitude 5° 32′; near the south side of the entrance to Belfast Lough. The gauge was nailed to the pier.

15. Ardglass.—A small harbour opposite to the Isle of Man; latitude 54° 15′, longitude 5° 35′. The gauge was nailed to the pier.

16. Clogher Head.—A headland a few miles north of Drogheda; latitude 53° 48′, longitude 6° 14′. The observations were made at a small harbour called Port Oriel, on the north side of the Head, but very near to it. The gauge was nailed to the pier.

17. Kingstown.—The harbour on the south side of Dublin Bay; latitude 53° 18′, longitude 6° 9′. The gauge was nailed to the wharf, on the landward side of the harbour.

18. Courtown.—A small harbour; latitude 52° 38′, longitude 6° 14′. The gauge was nailed to the wall of a canal which forms the opening from a small river into the sea.

19. Dunmore East.—A small port on the west side of the entrance of Waterford Harbour (the confluence of the rivers Barrow and Suir); latitude 52° 9′, longitude 6° 59′. The gauge was nailed to the pier.

20. New Ross.—A town on the river Barrow; latitude 52° 24′, longitude 6° 56′. The gauge was nailed to the bridge.

21. Passage West.—This is the western side of the narrow channel by which the waters of the river Lee, at Cork, principally enter into the broad harbour of Cork. Its latitude is 51° 53′, longitude 8° 21′. The tide-gauge was nailed to the face of the steam-boat wharf.

22. Castle Townsend.—A small harbour at very nearly the southernmost point of Ireland; latitude 51° 30′, longitude 9° 20′. The gauge was a pole in the sea.

Of these stations it may be remarked that Kilbaha, Kilrush, Foynes Island, and Limerick, are four stations in succession on the same river; that Dunmore East and New Ross are on the same river; and that Port Rush and Carrowkeel are nearly in the same circumstances: Casleh Bay and Galway are in a relation nearly resembling this. Kilbaha, Casleh Bay, Old Head, Mullaghmore, Port Rush, Ballycastle, Glenarm, Donaghadee, Ardglass, Clogher Head, Kingstown, Courtown, Dunmore East, and Castle Townsend, are all on the open sea; Kilrush, Galway, Buncrana, Carrowkeel, and Passage West, are somewhat removed from it.

The zero of the tide-gauge at each place was referred as early as possible in the course of the observations to a permanent mark (usually a copper bolt driven into the face of a rock), and these marks were all connected by a system of levellings, and thus the zeros of the tide-gauges were all referred to the same mark, namely, a copper bolt fixed in the upper surface of the heelstone or hinge-stone of the gate of Buckingham Lock, Dublin. To give the means of recovering this important zero, in the event of its loss, the following references were made to several public buildings in or near Dublin:—

Building.	Position of the mark on the building.	Elevation of the mark above the bolt at Buckingham Lock.
		feet.
Four Courts	Pavement or floor of portico at principal entrance	+0·928
General Post-Office	Pavement or floor of portico	+3·145
Bank of Ireland	Pavement or floor of colonnade at principal entrance	+6·113
Custom House	Pavement or floor of portico at principal entrance	+2·195
Carlisle Bridge	Copper bolt driven horizontally into the stone-work of the battlement, 3·900 feet below the top of the battlement, and 2·840 feet above the centre of the road	+8·705
Queen's Bridge	Copper bolt driven horizontally into the stone-work of the battlement, 4·450 feet below the top of the battlement, and 1·580 foot above the centre of the road	+8·019
Trinity College	An arrow cut on the stone-work at the principal entrance in College Green, 3·300 feet above the surface of the ground	+4·026
Poolbeg Light House	A mark on the surface of the base-course, under the south window (the mark lower than the bolt at Buckingham Lock)	−0·020

It will be seen, in the sequel, that results are obtained relating to the relative levels of the surface of the sea at different places, which if established must be deemed highly important. In order, therefore, to show what confidence is due to the results of relative level, I think it necessary to give, for every instance in which the means of doing so exist, the amount of discrepancy between the results for the difference of level between the same stations when the space between them was traversed by different lines.

	Description of marks whose difference of level is ascertained, and courses of the lines of levelling.		Approximate length of lines in miles.	Difference of level		Difference of backward and forward levelling.	Mean of backward and forward levelling.	Differences of the means by different lines.
				By forward levelling.	By backward levelling.			
				ft.	ft.	ft.	ft.	ft.
1.	Bolt in the front of the hotel, New Ross, above the bolt at Buckingham Lock, Dublin	By Monasterevan	101	10·698	11·826	1·128	11·262	0·171
		By Gorey	84	11·469	11·397	0·072	11·433	
2.	Mark at Lord Glengall's house, Cahir, below bolt in Monasterevan Church	By Borris-in-Ossery	72	48·203	48·482	0·279	48·342	0·418
		By Waterford	110	48·796	47·953	1·743	47·924	
3.	Bolt in Penrose Quay, Cork, below mark on William Street Bridge, Waterford	By Cahir	93	3·471	3·257	0·214	3·364	0·630
		By Dungarvan	85	3·973	4·015	0·042	3·994	
4.	Mark on Mead's Quay, Limerick, below mark at Court House, Borris-in-Ossery	By Nenagh	50	348·344	347·465	0·879	347·904	0·004
		By Holycross	68	347·661	347·940	0·279	347·800	
5.	Mark on Tralee Bridge, below mark on Holycross Bridge	By Limerick	105	272·575	273·262	0·687	272·918	0·264
		By Cahir and Mallow	122	272·389	272·920	0·531	272·654	
6.	Bolt in Loughrea Church, above the bolt at Buckingham Lock, Dublin	By Ballinasloe	108	268·558	268·993	0·435	268·775	0·135
		By Nenagh	130	268·762	268·519	0·243	268·640	
7.	Mark on Oranmore Bridge, above mark on Mead's Quay, Limerick	By Nenagh	76	7·573	7·981	0·408	7·777	0·336
		By Kilrush	109	8·341	7·886	0·455	8·113	
8.	Bolt in the Market House, Armagh, above the bolt at Buckingham Lock	By Dundalk and Newry	82	146·771	147·146	0·375	146·958	0·147
		By Navan, Cavan, Newtown Butler and Monaghan	118	147·061	146·561	0·500	146·811	
9.	Bolt in the front of Commercial Buildings, Belfast, below bolt on Sugar Island Bridge, Newry	By Armagh, Portadown, and Lisburn	58	5·477	5·489	0·012	5·483	0·056
		By Downpatrick and Newtown Ards	62	4·970	6·109	1·139	5·539	
10.	Bolt in Port Rush Pier, below bolt in Commercial Buildings, Belfast	By Glenarm and Ballycastle	83	6·327	5·086	1·241	5·706	0·908
		By Antrim and Coleraine	62	6·334	6·893	0·559	6·614	
11.	Bolt in Castlebar Gaol, below mark at Kinnegad	By Longford, Ballysadare and Ballina	140	98·589	98·341	0·248	98·465	0·487
		By Ballinasloe and Tuam	122	98·795	99·110	0·315	98·952	
12.	Bolt in Commercial Buildings, Belfast, below the bolt at Buckingham Lock	By Newtown Butler and Armagh	156	0·486	1·087	0·601	0·786	0·091
		By Newry, Downpatrick and Newtown Ards	125	0·289	1·122	0·833	0·695	
13.	Mark at Londonderry Bridge, above bolt at Buckingham Lock	By Newtown Butler, Monaghan and Strabane	168	2·828	3·351	0·477	2·589	1·058
		By lines round the east and north coasts	243	.....	.....	.....	3·647	
14.	Mark at Cliffony, near Mullaghmore, above bolt at Buckingham Lock	By Newtown Butler and Ballyshannon	139	93·998	93·117	0·881	93·557	0·140
		By Kinnegad and Ballysadare	145	92·520	94·314	1·794	93·417	

On these results, the following remarks are made by Colonel Colby.

The discordance in No. 10 is unusally great; but as it appears from an examination of the levelling that the error in discordance is of gradual accumulation and does not arise from any one mistake, the mean of the two results is adopted for Port Rush, and a part of the difference between this mean and the result on either line, proportional to the distance of any point on that line from Belfast, is adopted as a correction for the apparent elevation of such point.

In No. 13, second line, the comparison of forward and backward levelling is omitted, the principal part (namely that from Dublin to Port Rush) being contained in Nos. 10 and 12. The mean of the two results for Londonderry was adopted; upon this depend the zeros of Carrowkeel and Buncrana.

The station at Limerick being important, its relation of height to that at Dublin was ascertained by four different lines. The following Table contains the results of

these levellings. The first result, or that by the shortest line, was adopted in the reduction of the tide-observations.

Depression of the Bench-mark at Mead's Quay, Limerick, below the bolt at Buckingham Lock, Dublin.

Line along which the levels were carried.	Approximate length in miles.	Depression by forward levelling.	Depression by back levelling.	Mean of results forward and back.
		feet.	feet.	feet.
From Dublin by Monasterevan and Borris-in-Ossory; the difference of level from Borris-in-Ossory to Limerick being the mean of those found by Nenagh and by Holycross	127	0·629	0·651	0·640
From Dublin by Cork, Mallow, and Tralee; the difference of level from Dublin to Cork being the mean of those found by Monasterevan, Borris-in-Ossory, Cahir and Mallow, and by New Ross, Waterford and Dungarvan	317	0·032	0·744	0 388
From Dublin by Gorey, New Ross, Waterford, Mallow and Tralee; the difference of level from Waterford to Mallow being the mean of those by Cahir and by Cork	312	0·249	−0·350	−0·050
From Dublin by Ballinasloe, Oranmore, Liscanor and Kilrush	233	0·899	0·889	0·894

In order to give the means of verifying the principal results of the tide-observations at any future time, I subjoin a statement of the positions of the bench-marks at the different tide stations, and of their difference in elevation from the bolt at Buckingham Lock, Dublin.

Tidal Station.	Description of the permanent mark.	Elevation of the mark above the bolt at Buckingham Lock.
		feet.
Kilbaha	Top of copper bolt driven vertically into one of the facing-stones of the pier	− 2·814
Kilrush	Top of copper bolt driven vertically into one of the facing-stones of the pier	− 1·974
Foynes Island	Top of copper bolt driven vertically into the solid rock	− 2·920
Limerick	Copper bolt driven horizontally into one of the facing-stones at Russell's Quay	− 0·850
Casleh Bay	Top of copper bolt driven vertically into the solid rock, close to the Coast-Guard Watch House	+ 0·004
Galway	Copper bolt driven horizontally into one of the facing-stones at the entrance to the New Dock	− 3·000
Old Head	Copper bolt driven vertically into one of the facing-stones of the quay	− 0·870
Mullaghmore	Copper bolt driven vertically into one of the facing-stones of the south pier	− 1·749
Buncrana	Copper bolt driven horizontally into the scarpwall of Ned's Point Battery	+18·203
Port Rush	Copper bolt driven vertically into one of the facing-stones of the quay	− 6·900
Carrowkeel	Copper bolt in the wall of the Police barrack	+24·820
Ballycastle	Copper bolt driven vertically into one of the stones of the quay	− 2·268
Glenarm	Copper bolt driven into the solid rock on which the pier is built	− 9·388
Donaghadee	Copper bolt driven vertically into one of the facing-stones of the quay	+ 0·321
Ardglass	Copper bolt driven vertically into one of the facing-stones of the pier, near the steps	+ 0·838
Clogher Head	Mark on one of the facing-stones of the pier	+ 2·567
Kingstown	Top of copper bolt driven vertically into one of the facing-stones of the pier	− 2·796
Courtown	Top of copper bolt driven vertically into one of the facing-stones of the entrance to the harbour	− 4·459
Dunmore East	Top of copper bolt driven vertically into one of the facing-stones of the pier	− 3·711
New Ross	Mark in one of the facing-stones of the quay	− 4·178
Passage West	Top of copper bolt driven vertically into one of the coping-stones at the edge of the pier	− 6·463
Castle Townsend	Top of iron bolt driven vertically into the rock in which the Coast-Guard signal-staff is secured	+10·739

The results for height in the subsequent sections of this paper are all referred to a point thirty feet below the bolt at Buckingham Lock, Dublin.

At each of the stations the course of observation was as follows:—The observer adopted, as the tide which was to be completely observed, either the interval from high water to high water, or that from low water to low water, according to the convenience of the hours. Thus, having begun, for instance, with commencing a tide at the morning high water, when the high water occurred at convenient hours both in the morning and the evening; as the tides in the succession of days fell later and later every day, the termination of the tide at last fell inconveniently late in the evening, and the observer then began his observations about six hours earlier in the morning, so as to commence with low water and to terminate with low water. After a time it became necessary, in consequence of the evening low water occurring inconveniently late, to commence again with high water; and thus there was in every few days a change in the arrangement of observations.

The observations were generally commenced about half an hour before the commencing high water or low water, and were generally continued about half an hour after the terminating high water or low water. Thus, of the four principal phases which occur in each day (two high waters and two low waters), three were effectually observed in the day series of observations. As there were at each station at least two observers, one of these persons made observations for an hour or more in the night, partly before and partly after the remaining high water or low water; and thus all the high waters and low waters were observed. This system had the advantage of giving all the phenomena of diurnal tide, and giving one semidiurnal tide completely observed in each day, with little distress to the observer. Its only disadvantage is, that the observations at different stations do not always apply to the same portions of corresponding tides; but there appears to be no method of securing this precise correspondence of observations except by incessant observations day and night, or by self-registering tide-gauges. Each observer registered the height of the water on his tide-pole at every five minutes by his watch.

The watches were for the most part chronometers or lever watches. An officer visited each station at least three times, and the greater number of the stations four times, carrying a good pocket chronometer whose error on Greenwich time was known. Two itinerant chronometers were thus employed. The error of each of the observers' watches was afterwards computed for every day of observation from these comparisons, and this error was applied to form the corrected Greenwich time of every observation, in a column purposely left in the sheets of observations.

At two stations only, Ballycastle and Glenarm, the means for registering the time proved imperfect. At the former, in consequence of the failure of the watch, the time was taken from the town-clock, and corrected for the longitude of the place; it is supposed that this time may be sometimes ten minutes in error. I much regret that the extraordinary phenomena of the tides at Ballycastle are thus developed with

less certainty than could be desired; at the same time I have no hesitation in expressing my belief, that the credit of the results hereafter to be given is not sensibly injured by this circumstance. At Glenarm, from a similar cause, it became necessary to refer to the post-office clock; but the observations do not appear to have suffered materially.

The observations began about June 22, and were discontinued about August 22.

Section II.—*Methods of extracting from the observations the times of high and low water; of supplying deficient times and heights; and of correcting the times first determined.*

The determination of the height of the water, at high or low water, from the observations, was a matter of no difficulty. In two or three instances of low water, when the water had dropped below the zero of the tide-gauge, the observations were incomplete till it again rose to the zero; in these, the observations were supplied by comparison with other low waters which had been completely observed.

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The determination of the time was far more difficult. The examination of these observations has made me very distrustful of the results which have been deduced from observations of time only. The difficulty of fixing on the precise time of high or low water will appear from this statement, that sometimes twenty or twenty-four successive observations (occupying $1^h\ 40^m$, or 2^h) are registered with the same decimal of a foot for the height. The most perplexing case is that where the change of height, in respect to change of time, follows or may follow different laws before and after the principal phase. Thus at Limerick, after low water, the water sometimes rises as much in ten minutes as it had previously dropped in two hours; it therefore appears right here, if several successive observations about low water are registered at the same decimal of a foot, to suppose that the real low water is little before the last of those observations. At some other stations this circumstance does not happen uniformly; and then, when it does happen, it becomes difficult to say whether there is a difference of law before and after the low water (in which case the real low water ought to be taken nearer to the last observation), or whether the surface of the water at the last observations on the same division has been depressed by accident (in which case the real low water ought to be taken nearer to the first observations). I will not undertake to say that, in marking off the times of high and low water, I have followed a uniform method in these difficulties; but I have certainly followed a uniform plan for each station; and this is all that is important.

Occasionally, though rarely, observations of high and low water were interrupted by the roughness of the sea and other accidents. It was highly desirable to supply these, because (as will be seen in the next section) differences of the heights and of the times to the fourth order were to be taken, and thus the omission of one height or time would entail the loss of five results in these differences of the 4th order. The following is the process by which they were supplied. It very soon became

evident to all who inspected the collected heights at high and low water, that irregularities in the heights at any one station were sensible with no important difference of magnitude at the neighbouring stations. This will be abundantly shown in Section XI. On this assumption, a comparison of the height or time at one station with that at each of the neighbouring stations, for a few tides near to that at which the observation was deficient, would give the means of supplying the omitted height or time. But it was necessary to bear in mind that all the observations were affected by diurnal tide, and that the diurnal tide might vary sufficiently from port to port to render it unsafe to use comparisons of evening tides for the correction of morning tides, &c. The process adopted therefore was the following:—The results, both for times and for heights, were divided into four groups. One comprehended the high waters which next followed the moon's transit; these were called High Waters of the First Division. Another comprehended the low waters which next followed those high waters; these were called Low Waters of the First Division. The remaining high waters and low waters were called respectively High Waters and Low Waters of the Second Division. Each of these groups was treated separately. When a height or time of high or low water at any station was to be supplied, the observed height, &c. at that station was compared with the mean of the observed heights, &c. for at least two neighbouring stations, in at least two tides preceding and two tides following, in the same group; and the mean difference thus found was applied to the mean of the observed heights, &c. at the stations compared, on that day for which the tide was deficient. I have no doubt that the results thus supplied are sensibly as accurate as those which were actually observed.

On consideration of the difficulty of determining the times of high and low water, which has been already explained, it appeared necessary to endeavour to smooth down some of their irregularities, without at the same time endangering the conclusions as affected by difference of diurnal tides and of semidiurnal tides at the different stations. The following is the method employed:—Each of the groups already mentioned was separated into four subdivisions, determined by the proximity of stations. One included Kilbaha, Kilrush, Foynes Island, Limerick, Casleh Bay, Galway, and Old Head. The second included Mullaghmore, Buncrana, Port Rush, Carrowkeel, and Ballycastle. The third contained Glenarm, Donaghadee, Ardglass, Clogher Head, and Kingstown. The fourth contained Dunmore East, New Ross, Passage West, and Castle Townsend. [Courtown was omitted, because, as will be hereafter seen, no times of high or low water could be fixed for it.] Then each subdivision was treated separately. For each tide the mean of the times for all the different stations was taken (Buncrana, Ballycastle, and Glenarm, being excepted; as, from the small range of tide at these places, the determinations were more uncertain than at others). Then for every station (including those already named) the difference of the time from the mean of times was formed. Thus, for any one station, a difference from mean was obtained for each day. Let these differences for successive days be called

D_1, D_2, D_3, D_4, D_5, &c. Then the means of the adjacent numbers were taken,

$$\frac{D_1+D_2}{2},\ \frac{D_2+D_3}{2},\ \frac{D_3+D_4}{2},\ \frac{D_4+D_5}{2},\ \&c.;$$

and the means of the numbers in this series were taken, forming

$$\frac{D_1+2D_2+D_3}{4},\ \frac{D_2+2D_3+D_4}{4},\ \frac{D_3+2D_4+D_5}{4},\ \&c.$$

Then the number $\frac{D_1+2D_2+D_3}{4}$ was considered to be the just difference from mean for the second day in the series: it was applied to the mean of times for that day, and gave the adopted time for high or low water for that day, at the station under consideration; and so for the succeeding days. In regard to the legitimacy of this process, it is to be observed that it does not suppress the inequalities affecting, in different degrees at different stations, the semidiurnal or diurnal tide, provided the period of such inequalities is of several days. Nor does it suppress any accidental inequality which affects the whole tide-wave coming from the Atlantic upon a large extent of coast. The only failure is, that, as

$$\frac{D_1+2D_2+D_3}{4}=D_2+\frac{D_1-2D_2+D_3}{4}=D_2+\frac{1}{4}(\text{2nd difference});$$

when the second difference of D is large, an error is introduced. So long as the tides at the different stations follow anything like similar laws, there is no fear that this error will be perceptible. The only place where there is any probability that it can become sensible is Ballycastle; and here it will be very far below the irregularities of observation.

Section III.—*Theory of diurnal tide as related to observations only; and deduction of the principal results for diurnal tide given immediately by these observations.*

The remarks with which I shall immediately proceed apply equally to times and to heights, and equally to high waters and to low waters; but, to avoid unnecessary repetitions, I shall speak only of heights at high water.

Suppose then that, for any station, the heights at high water, both of the First Division and of the Second Division, have been collected and intermingled in the order of times. It is evident that the diurnal tide at any one of these heights will be found approximately by taking half the excess of that height above the mean of the two heights immediately preceding and immediately following. The number thus found will, however, be in error by one-fourth of the second difference of the semidiurnal tide. This error may be eliminated, leaving only an error depending on fourth differences, by taking half the algebraical excess of that apparent diurnal tide above the mean of the diurnal tides next to it.

The process may however be put in the following algebraical form:—Suppose the successive high waters to be affected with inequalities represented by $a.\cos n-3.t$,

$a.\cos\overline{n-2}.\theta$, $a.\cos\overline{n-1}.\theta$, $a.\cos n\theta$, $a.\cos\overline{n+1}.\theta$, $a.\cos\overline{n+2}.\theta$, &c., where n increases by unity for each successive high water. If we take the 4th, the 8th, the 12th, &c. differences of these numbers, we shall have for the differences standing opposite to $a.\cos n\theta$,

$$a.\cos n\theta \times 16 \sin^4\frac{\theta}{2},$$

$$a.\cos n\theta \times 256 \sin^8\frac{\theta}{2},$$

$$a.\cos n\theta \times 4096 \sin^{12}\frac{\theta}{2}.$$

Now if the inequality occupies many tides in going through its changes, that is, if θ is small, the powers of $\sin\frac{\theta}{2}$ will be very small, and these differences will therefore become smaller and smaller till they are nearly insensible. There is one value of θ, however, for which they do not become smaller, namely, that which makes $\sin\frac{\theta}{2}$ nearly $=1$, or θ nearly $=180°$, or in which the successive numbers $a.\cos\overline{n-1}.\theta$, $a.\cos n\theta$, $a.\cos\overline{n+1}.\theta$, &c. have nearly equal magnitudes with a change of sign at every step. It is evident that this is the case of diurnal tides. Consequently, on taking the successive differences in this manner, the diurnal tide will ultimately be the only inequality sensible.

If then we stop at the fourth differences, we may say that the diurnal tide $=\frac{\text{fourth difference}}{16\sin^4\frac{\theta}{2}}$: if we stop at the eighth difference, the diurnal tide $=\frac{\text{eighth difference}}{256\sin^8\frac{\theta}{2}}$; and so on, the expressions becoming more accurate as we advance further in the order of differences. Remarking, however, that the diurnal tide goes through all its changes in not fewer than 57 high waters, and that θ therefore differs from 180° by little more than 6°, or that $\sin\frac{\theta}{2}=\cos 3°$ nearly $=1-\frac{1}{800}$ nearly, we may consider the powers of $\sin\frac{\theta}{2}$ as equal to unity; and thus we have

$$\text{Diurnal tide} = \frac{1}{16}\times \text{4th difference},$$

$$\text{or} = \frac{1}{256}\times \text{8th difference},$$

&c.

The first of these formulæ was used throughout, both for heights and for times, and at both high and low waters.

Let us now consider the relation between the diurnal tide in height and that in time. Let θ be an angle increasing uniformly with the time, and increasing by 360° in a tidal day, its origin being the time of high water in the semidiurnal tide. Let a

be the diurnal tide at the first high water, b that at the first low water, c the semi-range of the semidiurnal tide. And suppose a and b to be so much smaller than c that their squares, &c. may be neglected. The height of the water above its mean height, on the law of elevation usually assumed, will be $a.\cos\theta+b.\sin\theta+c.\cos 2\theta$. This quantity will be maximum or minimum, or there will be high water or low water, when $-a.\sin\theta+b.\cos\theta-2c.\sin 2\theta=0$. The first approximation to the value of θ will be obtained by considering the large term only: from this we find $2c.\sin 2\theta=0$, from which $\theta=0$, or $=\frac{\pi}{2}$, or $=\pi$, or $=\frac{3\pi}{2}$, nearly. Substituting these values successively in the small terms, and supposing them liable to a correction x in the large term, we have,

For the first high water, $+b-2c.\sin(0+2x)=0$; or, nearly,

$$b-4cx=0\text{; whence } x=\frac{b}{4c}\text{, and } \theta=0+x=\frac{b}{4c}.$$

For the first low water, $-a-2c.\sin(\pi+2x)=0$; or, nearly,

$$-a+4cx=0\text{; whence } x=\frac{a}{4c}\text{, and } \theta=\frac{\pi}{2}+x=\frac{\pi}{2}+\frac{a}{4c}.$$

For the second high water, $-b-2c.\sin(2\pi+2x)=0$; or, nearly,

$$-b-4cx=0\text{; whence } x=\frac{-b}{4c}\text{, and } \theta=\pi+x=\pi-\frac{b}{4c}.$$

For the second low water, $+a-2c.\sin(3\pi+2x)=0$; or, nearly,

$$+a+4cx=0\text{; whence } x=\frac{-a}{4c}\text{, and } \theta=\frac{3\pi}{2}-\frac{a}{4c}.$$

It appears therefore that the diurnal equation in time at the High waters of the First Division has the same sign as, and is a certain multiple of, the diurnal equation in height at the Low waters of the First Division; and that the diurnal equation in time at the Low waters of the First Division has the same relation to the diurnal equation in height at the High waters of the First Division; and similarly for those of the Second Division. The factor by which the diurnal tide at low water in height is converted into diurnal tide at high water in arc is $\frac{1}{4c}$; and, observing that π in arc corresponds to about $12^h\ 24^m$ in time, the factor for converting diurnal tide at low water in height into diurnal tide at high water in minutes of time is $\frac{744}{4\pi.c}=\frac{186}{\pi.c}$; and that by which the diurnal tide at low water in minutes of time is converted into diurnal tide at high water in height is $\frac{\pi.c}{186}$. The same factor applies for converting diurnal tide at high water in minutes of time into diurnal tide at low water in height. But the high and low waters of the First Division must be used together, and the high and low waters of the Second Division must be used together.

This theory cannot be expected to apply with accuracy to any place far from the

sea (as Limerick or New Ross), where the law of the height of semidiurnal tide, as depending on the time, differs sensibly from that of $\cos 2\theta$.

Upon investigating the magnitude of the diurnal tides, by the method detailed a short time since, it appears that, at most stations, the diurnal tide in height was given with great regularity; but that, at the greater number of stations, the diurnal tide in time was not very regular. In order to compare the diurnal tides by means of the theory above, as well as for the purpose of ascertaining their magnitudes with some accuracy, it was necessary so to combine them that a mean of many determinations could be made available. This was done in the following manner:—

First, it is to be remarked that in this and all the following investigations the high and low waters of the first division only are used; these being evidently sufficient for the complete solution of any problem of diurnal tides.

Next, it is well known, or may be anticipated from the investigations of the next section, that on examining successively the diurnal tides at high water (first division) on successive days, they increase, diminish, change sign, and increase and diminish with the changed sign, in nearly the same manner as the sine of an arc increasing proportionally to the time; and that the same remark applies to the diurnal tides at low water.

The first thing to be done in investigation was therefore to ascertain when the diurnal tide vanishes. This was done by taking the five diurnal tides nearest to the estimated place of evanescence and combining them by the method of minimum squares, on the supposition that the diurnal tide ought there to alter by uniform steps; an assumption sensibly correct.

The next thing was, to take the mean of all the diurnal tides between two vanishing points. Supposing them to be expressed by the law $a.\sin\theta$, the mean of all these values is $\frac{\text{Sum of the values of } a\sin\theta}{\text{Number of values}}$, which is approximately expressed by $\frac{1}{\pi}a\int_{\theta}\sin\theta=\frac{2a}{\pi}$, and hence the coefficient a, or the maximum diurnal tide, must $=\frac{\pi}{2}\times$ the mean of the diurnal tides between two vanishing points.

The following results have been obtained by these methods:—

Diurnal Tide in Height at High Water. First Division.

Approximate time at Kilbaha. 1842.		Kilbaha.	Kilrush.	Foynes Island.	Limerick.	Caslech Bay.	Galway.	Old Head.	Mulraghmore.	Buncrana.	Port Rush.	Carrowkeel.	Ballycastle.	Glenarm.	Donaghadee.	Ardglass.	Clogher Head.	Kingstown.	Dunmore East.	New Ross.	Passage West.	Castle Townsend.
	hrs.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
June 22.	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	23.	18	.....	−0·23	.....	.....	−0·22	.....	−0·72	−1·05	−0·64	−0·72	−0·51	.....	−0·76	−0·72	−0·78	−0·75	−0·63	−0·24	−0·21	.....	+0·02
	24.	19	−0·40	−0·29	.....	.....	−0·26	−0·30	−0·64	−0·73	−0·86	−0·97	−0·78	.....	−0·83	−0·76	−0·78	−0·63	−0·59	−0·19	−0·18	−0·16	−0·02
	25.	19	−0·37	−0·26	−0·41	−0·30	−0·31	−0·34	−0·61	−0·99	−0·84	−0·81	−0·74	.....	−0·83	−0·85	−0·76	−0·69	−0·61	−0·13	−0·00	−0·16	0·00
	26.	20	−0·53	−0·50	−0·47	−0·46	−0·49	−0·42	−0·68	−0·99	−0·71	−0·58	−0·68	.....	−0·72	−0·76	−0·74	−0·71	−0·63	−0·13	−0·16	−0·14	0·00
	27.	21	−0·30	−0·40	−0·41	−0·42	−0·38	−0·40	−0·60	−0·91	−0·62	−0·56	−0·66	.....	−0·66	−0·71	−0·71	−0·73	−0·72	−0·14	−0·17	−0·17	−0·04
	28.	22	−0·30	−0·30	−0·36	−0·26	−0·34	−0·38	−0·40	−1·16	−0·70	−0·57	−0·63	−0·74	−0·65	−0·73	−0·79	−0·78	−0·75	−0·14	−0·18	−0·10	+0·01
	29.	22	−0·18	−0·24	−0·26	−0·24	−0·23	−0·27	−0·18	−0·88	−0·57	−0·49	−0·59	−0·53	−0·35	−0·54	−0·64	−0·67	−0·55	−0·09	−0·12	−0·02	+0·04
	30.	23	−0·09	−0·16	−0·13	−0·24	−0·12	−0·11	−0·14	−0·61	−0·64	−0·56	−0·67	−0·48	−0·32	−0·36	−0·48	−0·52	−0·39	−0·18	−0·12	−0·07	+0·01
July	2.	0	−0·01	−0·04	−0·03	−0·28	−0·02	−0·23	−0·20	−0·24	−0·56	−0·54	−0·61	−0·33	−0·30	−0·22	−0·32	−0·34	−0·25	−0·14	−0·15	−0·09	−0·14
	3.	1	+0·23	+0·04	+0·05	−0·19	+0·09	−0·13	+0·09	−0·38	−0·34	−0·28	−0·18	+0·06	+0·12	+0·11	+0·05	+0·02	+0·08	−0·25	−0·13	+0·01	−0·13
	4.	2	+0·26	+0·17	+0·09	−0·02	+0·20	+0·03	+0·07	−0·24	−0·28	−0·22	−0·06	+0·08	+0·16	+0·16	+0·19	+0·17	+0·16	−0·20	−0·06	+0·05	+0·13
	5.	3	+0·21	−0·06	+0·10	+0·25	+0·23	+0·11	+0·02	+0·05	−0·16	+0·01	−0·05	+0·16	+0·12	+0·06	+0·14	+0·17	+0·15	−0·04	+0·06	+0·11	+0·13
	6.	4	+0·11	−0·12	+0·12	+0·28	+0·16	+0·19	+0·28	+0·41	+0·16	+0·13	+0·05	+0·32	+0·27	+0·22	+0·21	+0·21	+0·20	+0·01	+0·06	−0·03	+0·04
	7.	4	+0·07	+0·13	+0·22	+0·46	+0·02	+0·12	+0·21	+0·41	+0·44	+0·46	+0·32	+0·51	+0·38	+0·41	+0·37	+0·17	+0·28	+0·11	+0·08	−0·03	−0·05
	8.	5	+0·24	+0·28	+0·42	+0·64	+0·14	+0·18	+0·20	+0·31	+0·52	+0·53	+0·56	+0·51	+0·56	+0·54	+0·51	+0·47	+0·45	+0·18	+0·21	+0·02	−0·08
	9.	6	+0·37	+0·31	+0·47	+0·72	+0·46	+0·32	+0·55	+0·76	+0·74	+0·57	+0·65	+0·61	+0·79	+0·72	+0·27	+0·58	+0·51	+0·11	+0·24	+0·11	−0·06
	10.	7	+0·29	+0·21	+0·22	+0·23	+0·22	+0·20	+0·42	+0·69	+0·51	+0·27	+0·25	+0·26	+0·59	+0·50	+0·34	+0·52	+0·39	+0·03	+0·11	+0·06	+0·03
	11.	8	+0·16	+0·24	+0·23	+0·22	+0·10	+0·21	+0·34	+0·84	+0·56	+0·43	+0·37	+0·40	+0·79	+0·67	+0·41	+0·56	+0·43	+0·11	+0·22	+0·16	−0·02
	12.	9	+0·26	+0·31	+0·28	+0·16	+0·27	+0·20	+0·47	+0·83	+0·45	+0·36	+0·39	+0·41	+0·98	+0·88	+0·69	+0·75	+0·56	+0·19	+0·28	+0·16	−0·02
	13.	9	+0·11	+0·12	+0·09	−0·02	+0·04	−0·09	+0·29	+0·82	+0·50	+0·40	+0·45	+0·44	+0·80	+0·71	+0·56	+0·66	+0·42	+0·11	+0·17	+0·11	−0·01
	14.	10	+0·04	+0·09	+0·06	−0·05	−0·05	−0·08	+0·21	+0·93	+0·44	+0·28	+0·25	+0·27	+0·69	+0·63	+0·49	+0·52	+0·37	+0·16	+0·12	−0·06	−0·07
	15.	11	+0·03	−0·01	−0·08	+0·03	−0·10	−0·07	+0·15	+0·62	+0·34	+0·29	+0·16	+0·27	+0·56	+0·49	+0·48	+0·33	+0·38	+0·13	−0·03	−0·01	−0·01
	16.	12	−0·12	−0·18	−0·23	−0·17	−0·24	−0·29	−0·20	+0·27	+0·27	+0·20	+0·02	+0·29	+0·27	+0·23	+0·21	+0·28	+0·11	+0·13	+0·01	−0·01	−0·02
	17.	13	−0·27	−0·20	−0·28	−0·47	−0·30	−0·37	−0·50	−0·01	+0·02	−0·02	−0·05	+0·01	−0·04	−0·09	+0·08	−0·04	−0·09	−0·01	−0·02	−0·06	−0·04
	18.	14	−0·33	−0·32	−0·35	−0·54	−0·24	−0·38	−0·27	−0·32	−0·29	−0·23	−0·28	−0·25	−0·23	−0·24	−0·22	−0·26	−0·23	−0·09	−0·12	−0·12	−0·08
	19.	15	−0·37	−0·18	−0·41	−0·40	−0·32	−0·31	−0·37	−0·52	−0·44	−0·41	−0·48	−0·38	−0·28	−0·28	−0·42	−0·36	−0·29	−0·16	−0·31	−0·18	−0·12
	20.	16	−0·41	−0·36	−0·41	−0·38	−0·39	−0·41	−0·57	−0·74	−0·61	−0·55	−0·64	−0·50	−0·34	−0·44	−0·50	−0·50	−0·39	−0·20	−0·35	−0·19	−0·13
	21.	17	−0·42	−0·34	−0·39	−0·41	−0·41	−0·41	−0·55	−0·79	−0·68	−0·62	−0·62	−0·58	−0·43	−0·51	−0·58	−0·52	−0·46	−0·21	−0·27	−0·19	−0·10
	22.	18	−0·42	−0·39	−0·38	−0·38	−0·40	−0·39	−0·50	−0·86	−0·73	−0·64	−0·74	−0·61	−0·48	−0·52	−0·60	−0·53	−0·54	−0·28	−0·33	−0·25	−0·15
	23.	18	−0·43	−0·40	−0·42	−0·37	−0·42	−0·35	−0·50	−0·90	−0·75	−0·40	−0·71	−0·63	−0·58	−0·62	−0·62	−0·66	−0·53	−0·19	−0·29	−0·24	−0·12
	24.	19	−0·42	−0·39	−0·39	−0·42	−0·43	−0·39	−0·59	−0·96	−0·64	−0·56	−0·58	−0·59	−0·64	−0·68	−0·69	−0·83	−0·49	−0·25	−0·28	−0·19	−0·09
	25.	20	−0·37	−0·36	−0·38	−0·38	−0·38	−0·33	−0·57	−0·87	−0·57	−0·52	−0·46	−0·53	−0·65	−0·65	−0·67	−0·66	−0·50	−0·20	−0·21	−0·16	−0·10
	26.	20	−0·33	−0·36	−0·33	−0·32	−0·33	−0·10	−0·45	−0·87	−0·59	−0·47	−0·37	−0·50	−0·58	−0·60	−0·65	−0·63	−0·55	−0·16	−0·26	−0·18	−0·03
	27.	21	−0·22	−0·25	−0·24	−0·32	−0·25	−0·21	−0·45	−0·73	−0·49	−0·33	−0·37	−0·46	−0·49	−0·58	−0·56	−0·71	−0·54	−0·14	−0·23	−0·10	−0·01
	28.	22	−0·14	−0·15	−0·16	−0·24	−0·19	−0·23	−0·35	−0·55	−0·42	−0·21	−0·16	−0·33	−0·45	−0·59	−0·50	−0·51	−0·48	−0·08	−0·18	−0·03	−0·01
	29.	22	−0·09	−0·03	−0·02	−0·07	−0·10	−0·05	−0·05	−0·50	−0·39	−0·24	−0·23	−0·29	−0·22	−0·34	−0·31	−0·18	−0·22	−0·19	−0·17	−0·05	+0·04
	30.	23	+0·01	0·00	+0·02	−0·09	0·00	+0·05	0·00	−0·11	−0·37	−0·47	−0·36	−0·30	−0·11	−0·16	−0·24	−0·21	−0·17	−0·14	−0·15	−0·06	+0·01
August	1.	0	+0·11	+0·11	+0·07	−0·04	+0·14	+0·10	+0·22	+0·09	−0·30	−0·27	−0·32	−0·02	+0·16	+0·10	−0·02	−0·04	+0·03	−0·04	−0·09	−0·07	−0·01
	2.	1	+0·21	+0·08	+0·20	+0·24	+0·25	+0·18	+0·57	+0·09	+0·01	+0·08	+0·03	+0·31	+0·35	+0·30	+0·16	+0·21	+0·24	−0·06	−0·06	−0·07	−0·04
	3.	2	+0·26	+0·07	+0·14	+0·22	+0·21	+0·12	+0·54	+0·10	+0·08	+0·03	−0·03	+0·21	+0·27	+0·20	+0·20	+0·21	+0·24	+0·04	+0·02	−0·04	−0·02
	4.	3	+0·27	+0·14	+0·19	+0·22	+0·21	+0·07	+0·43	+0·29	+0·33	+0·25	+0·23	+0·31	+0·20	+0·18	+0·15	+0·19	+0·21	+0·29	+0·12	+0·11	+0·12
	5.	4	+0·20	+0·09	+0·28	+0·34	+0·26	+0·17	+0·61	+0·69	+0·57	+0·56	+0·63	+0·58	+0·56	+0·52	+0·42	+0·55	+0·49	+0·28	+0·13	+0·20	+0·20
	6.	5	+0·14	+0·11	+0·20	+0·29	+0·17	+0·14	+0·44	+0·72	+0·51	+0·44	+0·32	+0·45	+0·53	+0·53	+0·54	+0·52	+0·47	+0·15	+0·22	+0·17	+0·11
	7.	6	+0·16	+0·19	+0·29	+0·36	+0·20	+0·21	+0·54	+0·68	+0·81	+0·70	+0·64	+0·65	+0·65	+0·62	+0·66	+0·49	+0·51	+0·28	+0·24	+0·17	+0·04
	8.	6	+0·33	+0·38	+0·44	+0·49	+0·45	+0·39	+0·69	+0·96	+0·83	+0·74	+0·89	+0·72	+0·97	+0·94	+0·85	+0·65	+0·69	+0·29	+0·34	+0·23	+0·03
	9.	7	+0·31	+0·33	+0·35	+0·36	+0·34	+0·30	+0·48	+0·90	+0·51	+0·41	+0·58	+0·44	+0·81	+0·80	+0·59	+0·53	+0·54	+0·18	+0·29	+0·22	+0·03
	10.	8	+0·16	+0·16	+0·22	+0·19	+0·11	+0·10	+0·27	+0·80	+0·50	+0·41	+0·44	+0·31	+0·87	+0·77	+0·56	+0·52	+0·61	+0·16	+0·16	+0·09	−0·04
	11.	9	+0·09	+0·10	+0·10	+0·08	−0·01	+0·07	+0·11	+0·72	+0·42	+0·19	+0·15	+0·14	+0·64	+0·74	+0·71	+0·56	+0·53	+0·01	+0·12	+0·03	−0·07
	12.	10	−0·03	−0·02	+0·02	−0·09	−0·11	−0·01	+0·08	+0·47	+0·15	+0·07	−0·06	+0·14	+0·68	+0·57	+0·57	+0·38	+0·55	−0·03	−0·03	−0·06	−0·08
	13.	11	−0·13	−0·12	−0·14	−0·24	−0·21	−0·15	−0·06	+0·15	−0·01	−0·08	−0·21	+0·19	+0·33	+0·27	+0·30	+0·20	+0·22	−0·06	−0·05	−0·06	−0·04
	14.	12	−0·31	−0·23	−0·26	−0·36	−0·28	−0·25	−0·28	−0·09	−0·09	−0·03	−0·19	+0·11	+0·12	+0·03	+0·01	+0·04	−0·09	−0·07	−0·09	+0·02	
	15.	13	−0·32	−0·20	−0·33	−0·43	−0·35	−0·33	−0·67	−0·46	−0·27	−0·25	−0·31	−0·17	−0·09	−0·15	−0·25	−0·14	−0·14	−0·19	−0·11	−0·10	−0·06
	16.	14	−0·27	−0·01	−0·31	−0·33	−0·32	−0·32	−0·44	−0·53	−0·39	−0·37	−0·48	−0·31	−0·22	−0·25	−0·39	−0·26	−0·22	−0·18	−0·18	−0·14	−0·09
	17.	15	−0·33	−0·04	−0·35	−0·40	−0·39	−0·38	−0·43	−0·69	−0·61	−0·55	−0·63	−0·42	−0·39	−0·41	−0·50	−0·41	−0·36	−0·06	−0·20	−0·23	−0·09
	18.	16	−0·29	−0·14	−0·25	−0·34	−0·26	−0·24	−0·44	−0·84	−0·66	−0·59	−0·55	−0·54	−0·34	−0·29	−0·32	−0·34	−0·26	−0·19	−0·17	−0·15	−0·03
	19.	17	−0·28	−0·24	−0·28	−0·41	−0·29	−0·29	−0·38	−0·96	−0·84	−0·74	−0·57	−0·85	−0·62	−0·54	−0·64	−0·66	−0·54	−0·21	−0·22	−0·17	−0·07
	20.	18	−0·32	−0·23	−0·37	−0·46	−0·38	−0·35	−0·62	1·03	−0·87	−0·72	−0·75	−0·77	−0·75	−0·69	−0·71	−0·79	−0·66	−0·23	−0·28	−0·19	0·00
	21.	19	−0·37	−0·31	−0·40	−0·45	−0·38	−0·43	−0·54	−0·88	−0·70	−0·59	−0·55	−0·57	−0·57	−0·63	−0·58	−0·66	−0·59	−0·23	−0·29	−0·21	−0·03
	22.	19	−0·31	−0·20	−0·35	−0·40	−0·35	−0·40	−0·50	−0·80	−0·60	−0·55	−0·50	−0·50	−0·50	−0·50	−0·50	−0·50	−0·45	−0·16	−0·20	−0·15	

Diurnal Tide in Height at Low Water. First Division.

Approximate time at Kilbahn. 1849.		Kilbahn.	Kilrush.	Poynes Island.	Limerick.	Castleh Bay.	Galway.	Old Head.	Mullaghmore.	Buncrana.	Port Rush.	Carrowkeel.	Ballycastle.	Glenarm.	Donaghadee.	Ardglass.	Clogher Head.	Kingstown.	Dunmore East.	New Ross.	Passage West.	Castle Townsend.
	hrs.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
June 22.	23	.....	.....	.....	.....	.....	.....	+0·47	+0·30	−0·30	−0·01	−0·32	.....	+0·40	.....	.....	.....	.....	.....	.....	.....	.....
23.	23	.....	.....	.....	.....	.....	.....	+0·47	+0·30	−0·30	−0·01	−0·32	.....	+0·65	+0·63	+0·56	+0·54	+0·59	−0·18	+0·03	.....	+0·03
25.	0	.....	+0·64	.....	+0·71	+0·60	+0·64	+0·14	−0·21	−0·06	−0·39	.....	.....	+0·73	+0·72	+0·55	+0·59	+0·58	−0·15	+0·03	−0·12	+0·03
26.	1	+0·53	+0·50	.....	+1·13	+0·57	+0·58	+0·53	+0·15	−0·19	−0·36	−0·33	.....	+0·43	+0·42	+0·35	+0·36	+0·32	−0·31	−0·19	−0·12	−0·03
27.	1	+0·46	+0·44	+0·55	+0·63	+0·46	+0·49	+0·36	+0·05	−0·39	−0·41	−0·26	.....	+0·36	+0·39	+0·38	+0·41	+0·25	−0·26	−0·10	−0·08	+0·01
28.	2	+0·49	+0·57	+0·65	+0·75	+0·55	+0·57	+0·41	+0·09	−0·33	−0·13	−0·09	+0·14	+0·40	+0·46	+0·48	+0·42	+0·04	−0·17	−0·06	−0·08	0·00
29.	3	+0·44	+0·50	+0·51	+0·61	+0·50	+0·52	+0·33	+0·16	−0·26	−0·02	−0·10	+0·14	+0·15	+0·32	+0·33	+0·37	+0·31	−0·23	−0·17	−0·04	+0·01
30.	4	+0·39	+0·40	+0·51	+0·63	+0·41	+0·52	+0·36	+0·26	−0·11	+0·06	+0·03	+0·14	+0·19	+0·30	+0·30	+0·32	+0·32	−0·11	−0·11	−0·01	+0·07
July 1.	5	+0·39	+0·41	+0·51	+0·95	+0·42	+0·45	+0·60	+0·50	+0·07	+0·14	+0·21	+0·09	+0·25	+0·34	+0·31	+0·38	+0·35	−0·11	−0·10	−0·10	−0·05
2.	6	+0·32	+0·19	+0·32	+0·47	+0·18	+0·26	+0·34	+0·41	−0·05	−0·06	0·00	−0·11	+0·19	+0·21	+0·18	+0·18	+0·22	−0·13	−0·08	−0·07	+0·04
3.	7	+0·24	+0·16	+0·23	+0·29	+0·13	+0·13	+0·25	+0·28	+0·06	+0·03	+0·04	+0·05	+0·27	+0·32	+0·28	+0·18	+0·29	+0·01	+0·07	+0·03	+0·13
4.	8	+0·20	+0·18	+0·10	−0·12	+0·16	+0·11	+0·28	+0·08	+0·03	+0·02	+0·06	+0·15	+0·43	+0·35	+0·29	−0·04	+0·16	+0·11	+0·25	+0·11	+0·06
5.	9	−0·14	−0·05	−0·21	−0·55	−0·19	−0·28	−0·04	+0·17	−0·17	−0·09	+0·01	−0·04	+0·10	+0·01	−0·11	−0·17	−0·17	+0·04	0·00	0·00	+0·08
6.	10	−0·34	−0·40	−0·49	−0·72	−0·45	−0·48	−0·26	+0·35	+0·05	−0·05	−0·01	−0·04	−0·17	−0·16	−0·16	−0·09	−0·18	0·00	−0·05	−0·04	+0·02
7.	11	−0·40	−0·60	−0·74	−1·16	−0·52	−0·61	−0·27	+0·40	+0·11	+0·11	+0·03	+0·06	−0·34	−0·39	−0·20	−0·37	−0·42	+0·05	−0·17	+0·01	−0·09
8.	12	−0·16	−0·71	−0·90	−1·37	−0·65	−0·68	−0·56	+0·09	−0·03	+0·07	−0·06	+0·02	−0·62	−0·64	−0·54	−0·64	−0·64	+0·03	−0·19	0·00	−0·27
9.	13	−0·34	−0·42	−0·61	−0·57	−0·46	−0·56	−0·62	+0·02	+0·26	+0·47	+0·30	+0·37	−0·39	−0·40	−0·38	−0·38	−0·32	+0·08	+0·03	+0·07	−0·17
10.	13	−0·23	−0·08	−0·51	−0·61	−0·46	−0·57	−0·73	−0·05	+0·12	+0·22	+0·16	+0·14	−0·51	−0·44	−0·34	−0·34	−0·27	+0·05	+0·23	+0·38	+0·03
11.	14	−0·60	−0·47	−0·58	−0·79	−0·67	−0·68	−0·82	−0·46	+0·09	+0·24	+0·17	+0·15	−0·70	−0·63	−0·58	−0·66	−0·56	+0·09	+0·06	+0·12	−0·05
12.	14	−0·44	−0·29	−0·55	−0·53	−0·50	−0·63	−0·61	−0·43	−0·09	+0·33	+0·35	+0·07	−0·57	−0·50	−0·49	−0·49	−0·42	+0·10	+0·19	+0·16	−0·03
13.	15	−0·39	−0·41	−0·55	−0·50	−0·39	−0·48	−0·55	−0·36	+0·10	+0·11	+0·25	−0·21	−0·64	−0·56	−0·58	−0·61	−0·56	+0·19	−0·10	+0·09	−0·09
14.	16	−0·27	−0·22	−0·29	−0·27	−0·27	−0·29	−0·44	−0·44	+0·09	+0·05	+0·13	−0·28	−0·39	−0·38	−0·44	−0·47	−0·44	+0·15	+0·09	+0·07	−0·25
15.	17	−0·20	−0·30	−0·16	−0·14	−0·24	−0·20	−0·37	−0·44	0·00	−0·01	+0·04	−0·30	−0·28	−0·23	−0·26	−0·14	−0·31	+0·16	+0·10	+0·11	−0·26
16.	18	−0·07	−0·09	−0·05	+0·05	−0·16	−0·39	−0·39	−0·45	+0·01	−0·10	+0·04	−0·27	−0·24	−0·19	+0·14	−0·23	−0·21	+0·06	−0·07	−0·04	−0·38
17.	20	+0·13	+0·12	+0·14	+0·14	+0·11	+0·03	−0·12	−0·20	0·00	−0·06	+0·01	−0·03	−0·01	+0·02	+0·08	−0·03	0·00	+0·01	−0·02	−0·08	−0·02
18.	21	+0·26	+0·28	+0·27	+0·26	+0·28	+0·25	+0·18	−0·19	−0·09	−0·10	+0·03	−0·08	−0·11	+0·17	+0·10	+0·11	+0·11	−0·09	−0·07	−0·02	0·00
19.	22	+0·33	+0·34	+0·36	+0·39	+0·36	+0·41	+0·33	−0·25	−0·15	−0·13	−0·04	−0·13	+0·09	+0·31	+0·23	+0·26	+0·24	−0·06	−0·14	−0·05	−0·01
20.	22	+0·41	+0·39	+0·45	+0·40	+0·45	+0·46	+0·59	−0·07	−0·14	−0·18	−0·12	−0·14	+0·42	+0·44	+0·36	+0·25	+0·32	−0·09	−0·15	−0·07	−0·02
21.	23	+0·43	+0·39	+0·46	+0·32	+0·51	+0·44	+0·56	+0·01	−0·16	−0·25	−0·21	−0·19	+0·45	+0·46	+0·36	+0·31	+0·29	−0·10	−0·11	−0·05	0·00
23.	0	+0·39	+0·35	+0·36	+0·27	+0·42	+0·33	+0·48	0·00	−0·21	−0·34	−0·24	−0·26	+0·47	+0·46	+0·38	+0·25	+0·27	−0·18	−0·18	−0·11	−0·06
24.	0	+0·41	+0·23	+0·40	+0·31	+0·45	+0·41	+0·48	−0·01	−0·28	−0·40	−0·32	−0·31	+0·44	+0·44	+0·35	+0·21	+0·31	−0·20	−0·13	−0·11	−0·01
25.	1	+0·36	+0·25	+0·46	+0·32	+0·46	+0·46	+0·47	+0·05	−0·31	−0·41	−0·34	−0·22	+0·38	+0·38	+0·30	+0·31	+0·27	−0·24	−0·15	−0·07	+0·08
26.	1	+0·33	+0·30	+0·41	+0·26	+0·45	+0·41	+0·40	+0·06	−0·24	−0·33	−0·25	−0·13	+0·31	+0·32	+0·30	+0·32	+0·27	−0·15	−0·15	−0·07	+0·04
27.	2	+0·35	+0·29	+0·38	+0·35	+0·42	+0·47	+0·34	−0·03	−0·19	−0·28	−0·25	−0·09	+0·23	+0·26	+0·28	+0·30	+0·26	−0·15	−0·14	−0·11	0·00
28.	2	+0·31	+0·36	+0·37	+0·55	+0·41	+0·52	+0·39	+0·04	−0·14	−0·23	−0·23	−0·04	+0·26	+0·28	+0·31	+0·35	+0·25	−0·28	−0·17	−0·10	+0·03
29.	3	+0·28	+0·31	+0·30	+0·39	+0·28	+0·41	+0·35	−0·05	−0·19	−0·18	−0·12	+0·02	+0·19	+0·19	+0·26	+0·28	+0·27	−0·15	−0·18	−0·10	+0·02
30.	4	+0·27	+0·21	+0·32	+0·48	+0·23	+0·29	+0·39	+0·21	+0·04	+0·04	+0·11	+0·11	+0·20	+0·19	+0·27	+0·31	+0·27	−0·06	−0·05	−0·01	−0·05
31.	5	+0·19	+0·15	+0·28	+0·41	+0·18	+0·17	+0·43	+0·34	+0·15	−0·07	+0·22	0·00	+0·09	+0·18	+0·25	+0·27	+0·19	−0·04	+0·01	0·00	−0·11
August 1.	6	−0·02	+0·07	+0·09	+0·10	+0·01	0·00	+0·21	+0·32	+0·11	+0·01	+0·01	−0·11	+0·14	+0·17	+0·11	+0·12	+0·11	+0·06	+0·05	0·00	−0·03
2.	8	−0·15	−0·08	−0·09	−0·21	−0·14	−0·08	+0·01	+0·27	+0·16	+0·06	+0·02	+0·02	+0·25	+0·16	+0·10	+0·23	+0·06	+0·09	+0·09	0·00	0·00
3.	9	−0·31	−0·29	−0·30	−0·48	−0·22	−0·16	−0·12	+0·14	+0·03	−0·07	−0·04	0·00	+0·12	+0·02	−0·12	+0·26	−0·21	+0·01	−0·04	−0·03	−0·04
4.	9	−0·37	−0·39	−0·44	−0·75	−0·33	−0·02	−0·36	−0·01	−0·01	−0·09	+0·12	−0·10	−0·26	−0·35	−0·40	−0·36	−0·39	−0·03	−0·09	−0·02	−0·02
5.	10	−0·51	−0·45	−0·60	−0·70	−0·58	0·00	−0·37	−0·04	+0·11	+0·19	+0·26	+0·06	−0·55	−0·58	−0·50	−0·42	−0·43	+0·11	−0·04	+0·08	+0·01
6.	11	−0·45	−0·32	−0·57	−0·47	−0·49	−0·42	−0·49	+0·18	0·00	+0·08	+0·11	+0·08	−0·71	−0·66	−0·62	−0·69	−0·50	+0·08	−0·01	+0·08	−0·01
7.	12	−0·71	−0·52	−0·68	−0·35	−0·60	−0·64	−0·72	−0·23	−0·03	+0·27	+0·20	+0·15	−1·04	−0·88	−0·82	−0·64	−0·64	+0·06	−0·09	+0·06	−0·06
8.	12	−0·48	−0·51	−0·49	−0·11	−0·61	−0·42	−0·61	−0·17	+0·34	+0·55	+0·47	+0·50	−0·66	−0·58	−0·55	−0·40	−0·39	+0·04	+0·13	+0·02	−0·06
9.	13	−0·34	−0·34	−0·34	−0·16	−0·40	−0·41	−0·63	−0·03	+0·26	+0·44	+0·29	+0·26	−0·53	−0·46	−0·45	−0·41	−0·41	+0·08	+0·12	+0·07	−0·04
10.	14	−0·26	−0·30	−0·28	−0·12	−0·29	−0·26	−0·57	+0·02	+0·33	+0·26	+0·31	+0·13	−0·42	−0·34	−0·36	−0·36	−0·38	+0·11	+0·08	+0·07	−0·09
11.	14	−0·15	−0·24	−0·18	−0·18	−0·15	−0·08	−0·57	−0·10	+0·37	+0·40	+0·36	+0·07	−0·33	−0·19	−0·19	−0·17	−0·17	+0·24	+0·10	+0·09	−0·17
12.	15	−0·04	−0·14	−0·09	−0·19	−0·05	−0·20	−0·51	−0·09	+0·37	+0·27	+0·16	+0·03	−0·09	−0·07	−0·09	−0·13	−0·14	+0·20	+0·04	+0·06	−0·05
13.	16	+0·05	−0·08	+0·04	+0·05	+0·06	+0·10	−0·27	−0·07	+0·09	+0·03	+0·01	−0·03	−0·02	+0·03	−0·01	−0·03	−0·06	+0·10	+0·04	+0·04	+0·04
14.	18	+0·17	+0·18	+0·26	+0·40	+0·21	+0·25	+0·04	−0·04	+0·08	−0·02	−0·01	+0·08	+0·18	+0·24	+0·21	+0·10	+0·13	+0·01	−0·04	−0·02	+0·01
15.	19	+0·23	+0·28	+0·27	+0·30	+0·27	+0·29	+0·20	−0·04	−0·07	−0·09	−0·13	+0·07	+0·20	+0·26	+0·21	+0·10	+0·20	−0·05	−0·09	−0·05	−0·02
16.	20	+0·34	+0·37	+0·35	+0·38	+0·41	+0·45	+0·39	+0·02	−0·11	−0·10	−0·14	+0·16	+0·39	+0·41	+0·32	+0·21	+0·21	0·00	−0·05	−0·04	0·00
17.	21	+0·35	+0·37	+0·40	+0·46	+0·40	+0·38	+0·39	−0·02	−0·14	−0·16	−0·20	+0·09	+0·52	+0·50	+0·38	+0·31	+0·19	−0·16	−0·13	−0·06	−0·01
18.	22	+0·39	+0·43	+0·49	+0·56	+0·43	+0·36	+0·50	−0·11	−0·09	−0·10	+0·07	+0·59	+0·54	+0·39	+0·40	+0·32	+0·08	+0·02	+0·02	+0·02	+0·08
19.	22	+0·38	+0·43	+0·48	+0·46	+0·42	+0·47	+0·45	−0·05	−0·12	−0·32	−0·22	−0·01	+0·59	+0·66	+0·54	+0·54	+0·49	−0·15	+0·02	−0·07	+0·01
20.	23	+0·43	+0·34	+0·43	+0·28	+0·42	+0·47	+0·38	−0·07	−0·33	−0·45	−0·43	−0·26	+0·39	+0·45	+0·34	+0·33	+0·32	−0·25	−0·16	−0·10	+0·01
21.	23	+0·36	+0·27	+0·37	+0·30	+0·35	+0·36	+0·18	−0·06	−0·33	−0·43	−0·46	−0·41	+0·30	+0·28	+0·21	+0·17	+0·11	−0·28	−0·18	−0·05	0·00
23.	0	+0·32	+0·25	+0·35	+0·25	+0·35	+0·40	+0·25	−0·07	−0·33	−0·43	−0·45	−0·35	+0·40	+0·35	+0·26	+0·25	+0·20	−0·28	−0·15	−0·07	+0·08

Times of Evanescence of Diurnal Tide in Height.

		d. July 1·73	d. July 14·97	d. July 30·72	d. Aug. 12·03
Kilbaha	High water.	July 1·73	July 14·97	July 30·72	Aug. 12·03
	Low water.	4·59	17·01	31·84	13·15
Kilrush	High water.	(1·8)	15·17	31·46	12·27
	Low water.	4·30	17·03	32·29	13·68
Foynes Island	High water.	1·98	14·74	30·74	12·31
	Low water.	4·27	16·98	32·64	13·19
Limerick	High water.	(1·9)	(14·7)	31·30	11·86
	Low water.	4·00	16·86	32·54	13·05
Casleh Bay	High water.	2·34	13·98	30·82	11·55
	Low water.	4·10	17·21	32·41	13·10
Galway	High water.	3·83	13·71	30·77	11·99
	Low water.	4·24	17·50	32·56	13·04
Old Head	High water.	(4·8)	15·62	31·36	12·38
	Low water.	5·22	18·11	33·46	14·80
Mullaghmore	High water.	4·61	17·63	32·53	14·17
	Low water.	(7·0)	(20·0)	(35·0)	(16·0)
Buncrana	High water.	5·38	17·56	33·32	13·74
	Low water.	(7·4)	(20·0)	(35·0)	15·63
Port Rush	High water.	5·09	17·26	33·43	13·47
	Low water.	(7·4)	(20·0)	(35·0)	14·92
Carrowkeel	High water.	4·96	16·66	33·26	12·69
	Low water.	(7·4)	(20·0)	(35·0)	(14·9)
Ballycastle	High water.	3·80	17·68	32·37	14·51
	Low water.	(6·4)	(19·0)	(34·0)	(13 9)
Glenarm	High water.	2·80	18·11	31·72	15·62
	Low water.	5·92	18·78	34·24	13·84
Donaghadee	High water.	2·82	17·91	31·85	15·35
	Low water.	5·34	17·92	33·18	13·56
Ardglass	High water.	3·76	18·00	32·82	15·10
	Low water.	5·57	16·11	33·47	13·71
Clogher Head	High water.	3·51	17·46	32·48	15·05
	Low water.	4·82	18·23	34·34	14·60
Kingstown	High water.	3·70	17·62	32·22	15·44
	Low water.	5·10	18·41	33·25	14·16
Dunmore East	High water.	6·01	17·44	33·40	12·39
	Low water.	3·56	18·31	32·13	15·88
New Ross	High water.	(6·0)	(17·4)	33·57	12·95
	Low water.	(3·5)	(18·3)	(32·1)	(15·8)
Passage West	High water.	(5·0)	(16·4)	33·76	12·27
	Low water.	(2·5)	16·91	(31·1)	14·75
Castle Townsend	High water.	(3·4)	(15·7)	(32·24)	(12·15)
	Low water.	(3·5)	(17·0)	(31·5)	(13·95)

The numbers inclosed in brackets are supplied by conjecture, where the irregularity of the tides made it difficult to discover with accuracy the times of evanescence. A small error in these will produce very little error in the result for maximum coefficient. The numbers at Castle Townsend (where the diurnal tide is very small) are the means between those for the adjacent stations, Passage West and Kilbaha. Courtown is omitted, as the peculiarity of the tides there made it impossible to take diurnal tides at high water and low water in the same manner as for the other stations.

The times when the moon's declination vanished are June $28^{d}\cdot89$, July $12^{d}\cdot14$, July $26^{d}\cdot18$, and August $8^{d}\cdot50$. In stating these, however, I must warn the reader that these are not the only elements on which the time of evanescence of diurnal tide depends, as will appear in the next section.

Attempts were made to determine, in the same manner, the times of evanescence of diurnal tide in time. The irregularities were however so great that in most cases it was useless to attempt to assign the day: in the following instances only did the results appear at all trustworthy.

Times of Evanescence of Diurnal Tide in Time.

		d	d	d	d
Mullaghmore.....	Low water.	July 7·19	July 20·76	July 31·96	Aug. 14·27
Buncrana	Low water.	3·30	20·41	30·77	16·02
Port Rush	Low water.	4·69	21·32	31·32	16·58
Carrowkeel.....	Low water.	1·37	19·01	30·50	16·39
Ballycastle	Low water.	5·11	18·16	36·43	15·05
Donaghadee	High water.	4·11	19·07	32·59	16·18
	Low water.	6·13	14·18	33·94	13·15

It will be remembered that the time of evanescence of diurnal tide in time at low water ought to coincide with that for height at high water, and *vice versâ*. The comparison of this table with that for height is not very satisfactory.

The maximum values of diurnal tide were deduced in all cases by the process explained a short time since, adopting for the times of evanescence the days given in the first table (or that from heights), and using the high water evanescence in height with the low water diurnal tide in time, and *vice versâ*. The following are the results:—

Maximum Values of Diurnal Tide, First Division: deduced from heights.

	High water.			Low water.		
	July 1—14.	July 14—31.	July 31—Aug. 12.	July 4—17.	July 17—32.	Aug. 1—13.
	ft.	ft.	ft.	ft.	ft.	ft.
Kilbaha	+0·28	−0·49	+0·30	−0·47	+0·52	−0·50
Kilrush	+0·20	−0·38	+0·25	−0·52	+0·42	−0·47
Foynes Island	+0·30	−0·45	+0·33	−0·74	+0·52	−0·58
Limerick	+0·30	−0·49	+0·36	−0·96	+0·49	−0·53
Casleh Bay	+0·27	−0·41	+0·30	−0·64	+0·52	−0·55
Galway	+0·24	−0·42	+0·25	−0·77	+0·57	−0·35
Old Head	+0·46	−0·61	+0·64	−0·69	+0·58	−0·74
Mullaghmore	+0·83	−0·80	+0·85	−0·30	+0·14	−0·08
Buncrana	+0·64	−0·75	+0·66	+0·05	−0·16	+0·25
Port Rush	+0·50	−0·57	+0·60	+0·14	−0·28	+0·35
Carrowkeel	+0·44	−0·93	+0·60	+0·17	−0·19	+0·33
Ballycastle	+0·50	−0·66	+0·58	+0·05	−0·16	+0·16
Glenarm	+0·74	−0·66	+0·82	−0·60	+0·42	−0·55
Donaghadee	+0·64	−0·74	+0·74	−0·64	+0·41	−0·71
Ardglass	+0·55	−0·74	+0·69	−0·60	+0·38	−0·58
Clogher Head	+0·64	−0·69	+0·60	−0·55	+0·36	−0·57
Kingstown	+0·53	−0·57	+0·64	−0·55	+0·36	−0·52
Dunmore East	+0·17	−0·24	+0·25	+0·13	−0·22	+0·11
New Ross	+0·22	−0·33	+0·25	+0·05	−0·22	+0·05
Passage West	+0·08	−0·20	+0·17	+0·13	−0·11	+0·06
Castle Townsend	−0·02	−0·09	+0·05	−0·16	−0·01	−0·08

These results are on the whole satisfactory. There are, however, some general differences of magnitude among the different columns, which I am not able at present entirely to explain. I may remark that the moon was in perigee on July 9 and August 7, and in apogee on July 25.

Maximum Coefficient of Diurnal Tide in Time, First Division.

	Low water.			High water.		
	July 1—14.	July 14—31.	July 31—Aug. 12.	July 4—17.	July 17—32.	Aug. 1—13.
	m	m	m	m	m	m
Kilbaha	+ 5·31	− 2·69	+ 4·25	− 6·22	+ 3·70	−0·98
Kilrush	+ 1·34	− 1·87	+ 1·75	− 5·92	+ 3·70	−3·18
Foynes Island	+ 4·10	− 4·00	+ 5·11	− 5·63	+ 1·70	−3·84
Limerick	+12·23	− 8·86	+ 8·15	− 3·91	+ 0·69	−5·63
Casleh Bay	+ 2·51	− 2·40	+ 3·18	− 8·73	+ 6·06	−4·29
Galway	+ 5·03	− 6·97	+ 3·08	− 8·73	+ 3·64	−4·98
Old Head	+ 2·87	− 2·96	+ 0·66	− 4·32	+ 4·13	+0·26
Mullaghmore	+ 3·93	− 7·77	+10·56	−10·48	+ 2·06	−5·09
Buncrana	+10·90	− 1·51	+ 7·90	− 0·42	+ 0·34	−1·73
Port Rush	+21·43	− 4·85	+16·77	− 1·88	+ 7·28	−3·14
Carrowkeel	+17·93	− 3·35	+14·92	− 5·60	+ 2·71	−0·68
Ballycastle	+28·28	−31·00	+17·26	− 3·42	+18·05	−1·96
Glenarm	− 1·76	− 7·82	+ 4·09	+ 0·66	+ 2·68	−2·20
Donaghadee	+ 0·04	− 6·58	+ 0·57	− 5·27	+ 1·72	−4·52
Ardglass	+ 1·72	− 4·41	+ 2·70	+ 0·07	− 4·47	−0·35
Clogher Head	+ 3·80	− 5·10	+ 1·86	− 0·01	− 2·47	−3·10
Kingstown	+ 4·32	− 5·46	+ 5·65	− 4·35	+ 0·52	−3·92
Dunmore East	+ 0·54	− 2·77	+ 3·31	+ 3·86	− 0·24	−2·40
New Ross	− 1·76	− 0·48	+ 3·45	+ 2·54	− 2·05	−4·99
Passage West	+ 2·71	+ 2·68	+ 0·96	+ 0·23	+ 0·70	−0·51
Castle Townsend	− 6·57	+ 2·12	− 1·26	− 2·49	+ 1·37	−3·67

After the statement which I have given (in the second section) of the difficulty of fixing upon times of high and low water, it will not be surprising that considerable irregularities exist among these numbers. Their agreement nevertheless is sufficient to show that the diurnal tide in time of low water is great at Limerick, and very great at all the stations from Buncrana to Ballycastle. At Mullaghmore and Ballycastle it is also great at high water. The increase in numbers at low water from Kilrush to Foynes Island and Limerick, would seem to show that diurnal tide in time at low water increases considerably in ascending a river. It would appear, however (as seems, *à priori*, probable), that this holds only when there is at the same time a considerable diurnal tide in height, of such a nature that a depression of height accompanies a retardation of time. This is supported entirely by the analogy of the course of low water at ordinary semidiurnal tide: where, as will appear in this paper, and as is known from other observations, and as also appears from theory*, the progress of the phase of low water up a river is slower as the water is shallower at low water. At New Ross, considered with relation to Dunmore East, the diurnal tide in time of low water is not sensibly increased; and here there is no large diurnal tide in height. The large numbers in the neighbourhood of Ballycastle do not depend on this cause.

Maximum Coefficient of Diurnal Tide in Height, First Division, as inferred from Diurnal Tide in Time.

	High water (from times of low water).			Low water (from times of high water).		
	July 1—14.	July 14—31.	July 31—Aug. 12.	July 4—17.	July 17—32.	Aug. 1—13.
	ft.	ft.	ft.	ft.	ft.	ft.
Kilbaha	+0·46	−0·18	+0·37	−0·59	+0·28	−0·13
Kilrush	+0·11	−0·14	+0·12	−0·62	+0·30	−0·37
Foynes Island	+0·41	−0·40	+0·61	−0·68	+0·19	−0·50
Limerick	+1·88	−1·16	+1·35	−0·61	+0·06	−0·81
Casleh Bay	+0·24	−0·16	+0·30	−0·92	+0·46	−0·45
Galway	+0·60	−0·51	+0·45	−0·87	+0·28	−0·68
Old Head	+0·28	−0·19	+0·07	−0·40	+0·24	+0·02
Mullaghmore	+0·16	−0·42	+1·02	−0·78	+0·17	−0·33
Buncrana	+0·97	−0·15	+0·75	−0·15	+0·04	−0·25
Port Rush	+0·77	−0·13	+0·73	−0·14	+0·14	−0·13
Carrowkeel	+0·97	−0·20	+0·85	−0·25	+0·11	−0·08
Ballycastle	+0·75	−0·42	+0·50	−0·11	+0·28	−0·08
Glenarm	−0·07	−0·31	+0·25	+0·05	+0·13	−0·13
Donaghadee	+0·06	−0·46	+0·10	−0·39	+0·11	−0·45
Ardglass	+0·27	−0·40	+0·33	−0·04	+0·37	−0·11
Clogher Head	+0·45	−0·45	+0·32	−0·03	−0·19	−0·41
Kingstown	+0·44	−0·40	+0·57	−0·39	+0·46	−0·38
Dunmore East	+0·04	−0·20	+0·34	+0·31	−0·02	−0·20
New Ross	−0·19	−0·06	+0·37	+0·26	−0·20	−0·43
Passage West	+0·26	+0·17	+0·09	+0·02	+0·08	−0·04
Castle Townsend	−0·45	+0·12	−0·15	−0·17	+0·09	−0·24

These numbers ought, upon the theoretical expressions for the tides given in an earlier part of this section, to agree with the numbers in the first table in page 19.

* Encycl. Metropol., *Tides and Waves*, Art. 208.

Upon comparing them it appears that there is a very good agreement of the numbers of the littoral stations, at both high and low waters, as far as Mullaghmore or even Buncrana; and, for high water only, as far as Ballycastle. There is then great discordance till we arrive nearly at Kingstown; in a short time after this the diurnal tide becomes so small that we are less surprised at apparent discordances. From the number of the instances in which the agreement is, upon the whole, pretty good, I form my opinion that the discordance between Buncrana and Kingstown is not accidental. I have little doubt that in this channel between Ireland and Scotland (which every accurate determination shows to be a critical part for the tides), the law of diurnal tide assumes a form differing much from that supposed in the investigation. It is, however, practically almost impossible to trace this law from observations.

The results for diurnal tide used in the subsequent investigations are those in the table of pages 15 and 16 deduced from observed heights only.

Section IV.—*Theory of Diurnal Tide as referred to the actions of the Sun and Moon.*

The present section will contain little more than the account of a series of failures of investigations. But the examination of these is usually so instructive that I think it desirable to state the heads of each of the unsuccessful attempts.

In order to explain the theoretical difficulties of this investigation, the following remarks may not perhaps be misplaced.

It is not possible to separate the effects of the sun and moon by comparison of a mass of observed diurnal tides near one solstice with a similar mass at the opposite solstice. For, although (in consequence of the opposite state of the moon's declination at a given phase of the lunation) the lunar diurnal tide is different in sign, yet the solar diurnal tide is also different in sign; and thus the two diurnal tides are mingled in the same degree at both solstices. The same applies if the observations are at any opposite seasons of the year.

It is possible to separate the two effects by comparing diurnal tides near a solstice with diurnal tides near an equinox; as, in the latter, the solar diurnal tide vanishes.

Generally, it is possible to separate them by comparing two masses of diurnal tides observed at intervals of three months; as for the high (or low) waters corresponding to a given right ascension and declination of the moon in the two masses, the sun will have widely different positions in hour-angle, and therefore its effects at those two instants will be widely different.

The proportion of the effects of the sun and the moon cannot be ascertained from a single series of observations, extending through a period so short that the sun's position may be considered invariable. This will be shown by showing that the two effects, of the sun and of the moon, in producing diurnal tide at high water, follow sensibly the same law, and when added together give a compound effect following the same law. Thus: the time of high water bears a nearly invariable relation to the

time of moon's transit; and therefore, at high water, the lunar diurnal tide is always in nearly the same phase, and has no variation except from the variation of its coefficient. The magnitude of the diurnal tide at semidiurnal high water may therefore be represented by coefficient $\times \sin\beta$; and that at semidiurnal low water by coefficient $\times \cos\beta$; where β is constant. This coefficient is proportional to the sine of the moon's declination at some time previous, or (nearly) proportional to the sine of the moon's right ascension for some time previous, or to the sine of the moon's hour-angle from the sun altered by a constant. For the solar diurnal tide, the coefficient is constant, but the phase varies every day. As the time of high water bears a nearly invariable relation to the time of moon's transit, the phase of solar diurnal tide at high water must depend upon the moon's hour-angle from the sun altered by a constant, and therefore the magnitude of solar diurnal tide will be proportional to the sine of the moon's hour-angle from the sun altered by a constant. Thus, putting $\mathfrak{C} - \odot$ for the excess of the moon's right ascension above the sun's, the lunar diurnal tide at the time of high water will be represented by $a.\sin\beta.\sin\{\mathfrak{C} - \odot + A\}$, and the solar diurnal tide at the same time will be represented by $b.\sin\{\mathfrak{C} - \odot + B\}$; and these, when added together, give a result of the same form, $c.\sin\{\mathfrak{C} - \odot + C\}$. And it is impossible to say whether this term, as given by observation, is entirely due to one or other of the two actions or to both combined; because we have no *à priori* means of saying what is the coefficient a or b of either of the separate terms; or what is the relation of the time of either high diurnal tide to the time of transit of the body which causes it, upon which A and B will depend. Everything here said with regard to semidiurnal high water applies also to semidiurnal low water; the only difference being that the angles β and B must be increased about 90° for semidiurnal low water.

The unknown quantities in the problem of diurnal tide are the following:—The interval anterior to the time of observation for which the moon's place is to be taken as governing the diurnal tide at the time of observation; the constant coefficient by which the sine of moon's declination for that anterior time is to be multiplied; the moon's hour-angle at the time of lunar diurnal high water; and the three similar quantities for the sun: in all, six unknown quantities. To determine these we have only the four following results of observation (or results equivalent to these four): the time of evanescence of diurnal tide at semidiurnal high water; the maximum of diurnal tide in high water, and the two similar quantities for low water. These are insufficient for the determination of the six unknown quantities; and we must try how we can reduce the latter number.

First, as the sun's declination is considered constant, the anterior interval for the sun's place is unimportant. And in fact, though the sun's declination during these observations (June 22 to August 25) was not invariable, yet an alteration of one day in the time for which its declination was taken as ruling the diurnal tide would not have been important. For the moon it would be very important.

Secondly, it seems probable that the moon's hour-angle at the time of lunar diurnal

high water does not differ much from the sun's hour-angle at the time of solar diurnal high water. The assumption of any constant difference, either $=0$ or having any assigned magnitude, reduces two of the unknown quantities to one.

The number of unknown quantities is thus made the same as the number of data, and the solution can therefore (speaking in a strictly algebraical sense) be effected, in general.

The following is the method by which the equations for the four unknown quantities may most conveniently be formed:—

From the ordinary facts of the tides, it seems probable that the coefficient of lunar diurnal tide may depend on the moon's declination at a few days, perhaps not exceeding five, anterior to the time of the tide. Let d_1 be the moon's declination at one day preceding the time of tide, d_3 the moon's declination at three days preceding the time of tide. Then we may express the coefficient of lunar diurnal tide by $p.\sin d_1+q.\sin d_3$; where by varying the proportions of p and q the coefficient may be made to depend on the moon's declination at any day near them; and by varying the magnitudes of p and q in the same proportion, the magnitude of the coefficient will be altered in that proportion.

The coefficient of solar diurnal tide may be represented with sufficient accuracy by $r.\sin D_1$, where D_1 is the sun's declination one day preceding the time of tide.

Let h be the solar hour of the tide. This is the same as the hour-angle of the sun to the west of the meridian. The phase of the solar diurnal tide will depend upon this angle diminished by some unknown constant s; and the elevation of the solar diurnal tide may be represented by $S.\sin D_1.\cos(h-s)$.

Let t be the moon's time of transit. Then the moon's hour-angle west of the meridian is $h-t$. Therefore if the phase of lunar diurnal tide depended on the moon's hour-angle in the same manner in which the phase of solar diurnal tide depended on the sun's hour-angle, the elevation of the lunar diurnal tide would be represented by $(p.\sin d_1+q.\sin d_3)\cos(h-t-s)$. But we know by the retardation of the period of spring tides, as well as by the theory of tidal waves affected by friction*, that in semidiurnal tides the lunar wave is more advanced in its phase with regard to the moon's hour-angle than the solar wave is with regard to the sun's hour-angle. We may conjecture, by analogy, that the same holds for diurnal tide. Putting α for this difference of advance of phase, the elevation of the lunar diurnal tide will be represented by $(p.\sin d_1+q.\sin d_3)\cos(h-t-s+\alpha)$. And the compound effect of lunar and solar diurnal tides, expanding the cosines, will be

$$S.\sin D_1.(\cos h.\cos s+\sin h.\sin s)$$
$$+(p.\sin d_1+q.\sin d_3)(\cos(h-t+\alpha).\cos s+\sin(h-t+\alpha).\sin s).$$

Let $S.\cos s=w$, $S.\sin s=x$, $\frac{p}{S}=y$, $\frac{q}{S}=z$; and the expression becomes

* Encyclopædia Metropolitana, *Tides and Waves*, Art. 326.

$$\sin D_1.\cos h.w+\sin D_1.\sin h.x+\sin d_1.\cos\overline{h-t+\alpha}.wy+\sin d_1.\sin\overline{h-t+\alpha}.xy$$
$$+\sin d_3.\cos\overline{h-t+\alpha}.wz+\sin d_3.\sin\overline{h-t+\alpha}.xz.$$

It is to be remarked that, when w, x, y, and z, are ascertained (with an assumed value of α), the following more intelligible results will be extracted from them:—

$S=\sqrt{w^2+x^2}=$ solar coefficient of the sine of the sun's declination, for solar diurnal tide.

$s=$ the angle determined by the equation $\tan s=\frac{x}{w}$; it is the constant angle which is to be subtracted from the sun's hour-angle west at the time of observation, in order to give the angle on whose cosine depends the height of solar diurnal tide at the instant of observation.

Then, the lunar diurnal tide

$=(p.\sin d_1+q.\sin d_3)\cos\overline{h-t-s+\alpha}=S.(y.\sin d_1+z.\sin d_3).\cos\overline{h-t-s+\alpha}$;

and, {putting l for the moon's longitude measured from the intersection of its orbit with the equator, I for the sine of its inclination, and δ for the mean daily increase of longitude from transit to transit $=13^\circ\,38'$}, $y.\sin d_1+z.\sin d_3=I(y.\sin l_1+z.\sin l_3)$

$$=I\left(\frac{z+y}{2}.\sin l_3+\sin l_1+\frac{z-y}{2}.\sin l_3-\sin l_1\right)=I(\overline{z+y}.\cos\delta.\sin l_2+\overline{z-y}.\sin\delta.\cos l_2);$$ or,

if $\tan\eta=\frac{z-y}{z+y}\tan\delta$, this quantity becomes $=I.\overline{z+y}.\cos\delta.\sec\eta.\sin\overline{l_2+\eta}$; or, making $\eta=n.\delta$, it becomes $=I.\overline{z+y}.\cos\delta.\sec\eta.\sin l_{2+n}=\overline{z+y}.\cos\delta.\sec\eta.\sin d_{2+n}$: and therefore the lunar diurnal tide $=S.\overline{z+y}.\cos\delta.\sec\eta.\sin d_{2+n}.\cos\overline{h-t-s+\alpha}$.

$$\frac{M}{S}=\frac{\text{Effect of moon for given declination}}{\text{Effect of sun for same declination}}=\overline{z+y}.\cos\delta.\sec\eta.$$

$M=S.\overline{z+y}.\cos\delta.\sec\eta=$ lunar coefficient of the sine of the moon's declination on a certain anterior day, for lunar diurnal tide.

$2+n=$ the time, in lunar days, earlier than the moon's Greenwich transit next preceding, for which the moon's declination is to be taken as governing the diurnal tide. This is correct for the time of high water, first division, and requires an alteration for other times. n is $=\frac{\eta}{13^\circ\,38'}$; and $\tan\eta=\frac{z-y}{z+y}\cdot\tan 13^\circ\,38'$.

$s-\alpha=$ the constant angle which is to be subtracted from the moon's hour-angle, in the same manner as s from the sun's hour-angle.

The factors of the unknown terms w, x, wy, wz, xy, and xz, in the algebraical expression for the elevation produced by diurnal tide, were computed for high water and low water, first division, at Kilbaha, for every day throughout the observations. These computations would apply equally to the other stations, it being understood that certain constants (which the reader will easily investigate) depending on the longitude of the station and the time occupied by the passage of semidiurnal tide, are to be applied to the angles α and s. The hour-angles used for the moon were found by comparing the moon's time of transit at Greenwich with the time of Kil-

baha tide. The declinations were those for the times of transit at Greenwich one day and three days previous to the transit next preceding the tide in question. For the low waters of the first division, which follow the high waters of the first division by $\frac{1}{4}$th of a tidal day, the right ascensions and declinations ought to be taken for transit over the 6^h meridian; this was done most conveniently by correcting the coefficients when combined in groups, by the following formulæ. If the computed terms containing w and x for the moon are $W.w+X.x$ {W and X containing y and z}, then the corrected terms as altered for the change of right ascension, are

$$\left(W\cos\tfrac{\delta}{4}+X\sin\tfrac{\delta}{4}\right)w+\left(X\cos\tfrac{\delta}{4}-W\sin\tfrac{\delta}{4}\right)x.$$

And if the computed terms containing y and z are $Y.y+Z.z$ (Y and Z containing w and x), then the corrected terms as altered for the change of declination, are

$$\left(Y.\frac{\sin\left(2\delta+\frac{\delta}{4}\right)}{\sin 2\delta}-Z\frac{\sin\frac{\delta}{4}}{\sin 2\delta}\right)y+\left(Z\frac{\sin\left(2\delta-\frac{\delta}{4}\right)}{\sin 2\delta}+Y\frac{\sin\frac{\delta}{4}}{\sin 2\delta}\right)z.$$

No notice was taken of the changes of parallax; nor were the hour-angles referred to the moon's place one or three days previous (as in strictness of theory they ought); but as the observations extend over two whole lunations, it was supposed that the effects of these omissions would nearly disappear.

The factors of the unknown quantities were computed on the supposition that $\alpha=0$, and also on two other suppositions. It is easily seen, however, that the factors for any assumed value of α can be readily formed from those which hold for $\alpha=0$; and this computation is made most conveniently for the groups.

The numbers for high water were divided into groups related to the changes of sign of the factors of w and x. These groups were then combined in the order 1st + 2nd − 3rd − 4th + 5th + 6th − &c. to form one equation, and in the order 1st − 2nd − 3rd + 4th + 5th − &c. to form another equation. The numbers for low water were treated in the same way. In subsequent operations, the groups were formed and combined in different orders.

But, in whatever way the groups were formed, they were so combined as to form four equations, each of which has the following form:

$$A.w+B.x+C.wy+D.wz+E.xy+F.xz=G.$$

To solve a system of four such equations is evidently no easy matter. Two methods of solution were principally relied on.

The first (and easiest) was, to make trial-substitutions to a great extent. The numbers −2, −1, 0, +1, +2, were substituted for w; the same numbers were substituted for x; the same numbers were also substituted for y and for z; and every possible combination of these numbers was used; making 625 trial-substitutions in each of the four equations. And when there seemed a probability of success, the substitutions for one or two of the numbers were greatly extended. Calling the re-

sults of one substitution in the four equations g, g', g'', g''' (the numbers resulting from the tidal observations being G, G′, G″, G‴), it was then necessary that

$$\frac{g'}{g}=\frac{G'}{G},\ \frac{g''}{g}=\frac{G''}{G},\ \frac{g'''}{g}=\frac{G'''}{G}.$$

By search among the quotients of the substitution, numbers were found approaching as near as possible to $\frac{G'}{G}$, &c.; then, supposing w unaltered, the variations of the quotients were found, which corresponded to changes of 1 in x, y and z; from these, by solving three linear equations, the corrections to x, y and z were found; and then a common multiplier for w and x was found by comparing the result of each corrected substitution with the tidal numbers G, G′, &c.

The other method was, to put the equations in the following form:

$$w\times(A+C.y+D.z)+x\times(B+E.y+F.z)=G.$$

Between two of the equations, w and x were eliminated, and a complicated equation between y and z remained; another equation of the same character was obtained from the other two of the original equations; and these two equations were solved by trials.

By these methods (but principally by the former) the equations were solved for $\alpha=0$ and $\alpha=-2^h$ for all the stations as far as Mullaghmore. Beyond that station it was found totally impracticable to solve them. Values of w, x, y, z were sometimes found which seemed nearly to satisfy the equations, but when an attempt was made to correct these values, the corrections became absurdly large, and the corrected values gave results much further from the truth than the original results. And for those stations at which the operation was successful, there were special results of inadmissible character. Thus, when $\alpha=0$, $\frac{M}{S}$ was found $=4{\cdot}30$ for Kilbaha, and $=1{\cdot}45$ for Mullaghmore; when $\alpha=-2^h$, $\frac{M}{S}$ was found $=3{\cdot}40$ for Kilbaha and $=0{\cdot}82$ for Mullaghmore. These discordances seemed to show that α must be positive; but in no case could a solution be obtained with a positive value for α.

On examining carefully the numbers given by observation, I was led to the following considerations, which seemed likely to throw considerable light on the subject.

On inspecting the table in page 17, it will be evident that at the first stations, as far as Old Head, the disappearance of diurnal tide at high water does not occur on the same day as the disappearance of diurnal tide at low water; the former always occurring earlier than the latter. But at the stations from Glenarm to Dunmore East, the disappearance of diurnal tide at high water sometimes precedes and sometimes follows that at low water; and may be said, roughly speaking, to occur on the same day. This circumstance fixes absolutely the value of α. For, when the diurnal tide at high water and that at low water vanish at the same time, the inference is, that at that time the lunar diurnal tide and the solar diurnal tide have equal values

with opposite signs four times in their diurnal period. If then their phases at the first of those four times be represented by φ and ψ respectively, and their coefficients by μ and ν, we have

$$\mu \sin \varphi + \nu \sin \psi = 0, \qquad \mu \sin (\varphi + 90°) + \nu \sin (\psi + 90°) = 0,$$

$$\mu \sin (\varphi + 180°) + \nu \sin (\psi + 180°) = 0, \quad \mu \sin (\varphi + 270°) + \nu \sin (\psi + 270°) = 0.$$

The solution of these equations is either $\mu = -\nu$, $\varphi = \psi$; or $\mu = \nu$, $\varphi = \psi + 180°$. Confining our expressions to the former (by which we lose nothing of generality), we have this result; that, upon that day, the solar diurnal tide and the lunar diurnal tide are in the same phases at every part of the day. Observing then that α is the angle which is to be added to the moon's hour-angle west, in order to give it the same relation to the phase of lunar diurnal tide which the sun's hour-angle west has to the phase of solar diurnal tide, it will be seen that α must be equal to the excess of the moon's right ascension over the sun's right ascension (altered by 12^h if necessary) on the day on which the diurnal tide vanishes both at high and low water.

In order to investigate the value of α with accuracy, the following process was used:—If from the table in page 17 we form the numbers "day of evanescence at low water — day of evanescence at high water," at Glenarm, or Donaghadee, &c., it will be seen that the four numbers at the same station have values alternately greater and less. This is owing, I conceive, to parallax, or some other cause which is periodical in one revolution of the moon nearly; and a correction is probably necessary, applicable with opposite signs to the alternate values. Thus, comparing the second with the mean of the first and third, half the difference is one value of the correction; comparing the third with the mean of the second and fourth, half the difference is another value of the correction; and the mean of these may be used. Thus corrected values of the "day of evanescence at low water — day of evanescence at high water" were obtained. Taking the means of the corresponding corrected values for the six stations from Glenarm to Dunmore East, we have,

About July .	$4^d{\cdot}41$,	the mean value is	$0^d{\cdot}76$,	{ and the excess of the moon's R.A. over the sun's R.A. is }	$20^h\ 46^m$
About July .	$17{\cdot}86$,	the mean value is	$0{\cdot}73$	„ „ „	$8\ 33$
About August	$1{\cdot}92$,	the mean value is	$0{\cdot}47$	„ „ „	$19\ 58$
About August	$14{\cdot}56$,	the mean value is	$0{\cdot}00$	„ „ „	$7\ 13$

From the regularity of the progress of the numbers in the second and third columns, it appears certain that the value $7^h\ 13^m$ for α must be very near the truth.

From the reasoning above it will appear that, in the case of simultaneous evanescence of diurnal tide at high water and at low water, we have no means whatever of ascertaining the values of μ and φ on that day. Or, if we take the expressions on page 22, we have for diurnal tide at high water,

$$a.\sin\beta.\sin\{\mathfrak{C} - \odot + A\} + b.\sin\{\mathfrak{C} - \odot + B\},$$

and at low water,

$$a.\cos\beta.\sin\{\mathfrak{C} - \odot + A\} + b.\cos\{\mathfrak{C} - \odot + B\};$$

and, on the same day when both vanish,

$$\beta \text{ must} = \mathfrak{C}' - \odot' + B \text{ and } a\sin\{\mathfrak{C}' - \odot' + A\} \text{ must} = -b;$$

by which the expression for diurnal tide at high water is changed to

$$a.\sin\{\mathfrak{C}' - \odot' + B\}.\sin\{\mathfrak{C} - \odot + A\} - a.\sin\{\mathfrak{C}' - \odot' + A\}.\sin\{\mathfrak{C} - \odot + B\}$$
$$= a.\sin(B-A).\sin\{\overline{\mathfrak{C} - \odot} - \overline{\mathfrak{C}' - \odot'}\},$$

and that at low water is changed to

$$a.\cos\{\mathfrak{C}' - \odot' + B\}.\sin\{\mathfrak{C} - \odot + A\} - a.\sin\{\mathfrak{C}' - \odot' + A\}.\cos\{\mathfrak{C} - \odot + B\}$$
$$= a.\cos(B-A).\sin\{\overline{\mathfrak{C} - \odot} - \overline{\mathfrak{C}' - \odot'}\}.$$

The maximum of the compound diurnal tide at high water will then be $a.\sin(B-A)$, and that at low water $a.\cos(B-A)$. From the observed values of these maxima we may obtain the values of a and $B-A$; but we cannot from these obtain either A or B, or $a.\sin\beta$, or b; and thus the separation of the solar and lunar diurnal tides is in this case impossible.

As it seemed probable that the same value of α ($7^h\ 13^m$), which was inferred from these stations, would apply to the other stations also, I changed the equations for w, x, y, z, to the form corresponding to $\alpha = 7^h\ 13^m$. But, on attempting to solve them for Kilbaha, Kilrush, &c., I was entirely baffled. I could not in any instance approach to a solution.

As a last resource I resorted to the following method. Although the observations cannot be supposed competent to furnish more than four unknown quantities, yet they may be combined, and with sufficiently favourable coefficients, for the determination of the six quantities w, x, wy, wz, xy, xz: as the equations will be simple, values can certainly be found for these quantities; and then the accuracy of the results will be tested by ascertaining whether the following equations hold; $\frac{wy}{w} = \frac{xy}{x}$, $\frac{wz}{w} = \frac{xz}{x}$. In this manner then equations were formed and solved for the principal stations; but at none of them was there any approach towards satisfying the equations of condition which I have just given; nor even upon reducing the results to a common phase of the diurnal tide-wave, by means of the intervals of diurnal establishment to be given in Section IX., and taking the mean, was there any approach towards satisfying those equations. This is the last attempt that I made, and I confess myself, on the whole, completely unsuccessful.

The following considerations may perhaps explain the failure of all these attempts. We have seen that when the days of evanescence, of diurnal tide in semidiurnal high water, and of diurnal tide in semidiurnal low water, coincide, it is absolutely impossible to extract from the equations a result relating to the distinction of solar and lunar effects. It may therefore be inferred that, when the days of evanescence *nearly* coincide, the determination of the quantities sought will be *nearly* impossible, or will be liable to very great errors. Now, at all the stations the interval between

the days of evanescence for semidiurnal high water and for semidiurnal low water is small, and therefore it appears that in the case of the Irish tides in question, the difficulty of separating the solar and lunar effects is inevitable.

A treatment of the phenomena of diurnal tide which does not lead to a distinction of the solar and lunar effects must be considered as imperfect. And it has been explained that, though from a short series of observations the distinction cannot be extracted, it can with certainty be obtained from a long series of observations. With a full avowal of the completeness of my own failure and with a statement at the same time of what science requires and what it may reasonably expect, I may be permitted to explain an expression which I have used in my tract on Tides and Waves, Art. 564, where I have said that a determination by Mr. WHEWELL is worth little. My intention was to express that the distinction of the solar and lunar effects was theoretically important, that it might be obtained from the observations there referred to, and that it was not obtained. In stating that Mr. WHEWELL's determination was worth little, my expression was thus far incorrect, that a general rule for the order of diurnal tides, though liable to some inaccuracy, was really obtained by Mr. WHEWELL. I regret that I should have made a statement which could thus seem to be insufficiently founded, and still more that I should have expressed it in a phrase which could be interpreted as lightly esteeming the deductions of the writer to whom we are indebted more than to any other for the knowledge which we possess regarding the laws of the tides.

Section V.—*Discussion of the height of apparent mean water, as deduced from the heights of high and low water only, corrected for diurnal tide; with reference to difference of station, and to variations of the magnitude of the tide and of the moon's declination.*

The heights at high and low water were corrected for the diurnal tide in height found in Section III. The age of the semidiurnal tide as deduced from heights having been found (by the process of the next section) to be about two days, the times were taken from the Nautical Almanac, at which the moon's hour-angle from the sun was 3^h, 9^h, 15^h, 21^h, and two days being added to these, the times were determined which were to be used as separating the large tides from the small tides. The groups of observations thus marked off were the following:—

	d	h		d	h	
1st Group, June	28	6	to July	6	16,	small tide.
2nd Group, July	6	16	to July	13	3,	large tide.
3rd Group, July	13	3	to July	20	9,	small tide.
4th Group, July	20	9	to July	28	9,	large tide.
5th Group, July	28	9	to August	5	0,	small tide.
6th Group, August	5	0	to August	11	16,	large tide.
7th Group, August	11	16	to August	18	15,	small tide.

For each of these groups the mean of the heights at high water was taken, and the mean of the heights at low water was taken. Then the mean of the determinations of each of these classes in the 1st, 3rd, 5th, and 7th groups was taken, and thus was obtained a mean height at high water and a mean height at low water in small tides. The mean of these two means gave the Apparent Mean Height in small tides (so called in order to distinguish it from the Mean Height which will be found in Section XI.). By a similar treatment of the 2nd, 4th, and 6th groups, the mean height at high water, mean height at low water, and Apparent Mean Height, in large tides, were found. The results are as follows:—

Station.	Small Tides.			Large Tides.			Mean of Apparent Mean Heights.	Excess of Apparent Mean Height in large tides above Apparent Mean Height in small tides.
	Mean height at high water.	Mean height at low water.	Apparent Mean Height.	Mean height at high water.	Mean height at low water.	Apparent Mean Height.		
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
Kilbaha	19·34	11·92	15·63	21·79	9·57	15·68	15·65	+0·05
Kilrush	20·50	12·06	16·28	22·96	9·77	16·37	16·32	+0·09
Foynes Island	21·82	11·68	16·75	24·39	9·13	16·76	16·75	+0·01
Limerick	23·22	9·99	16·61	26·38	7·40	16·89	16·75	+0·28
Casleh Bay	21·81	14·12	17·97	24·43	11·52	17·98	17·97	+0·01
Galway	21·54	13·42	17·48	24·34	10·70	17·52	17·50	+0·04
Old Head	21·18	14·28	17·73	23·60	12·04	17·82	17·77	+0·09
Mullaghmore	21·22	14·78	18·00	23·42	12·92	18·17	18·08	+0·17
Buncrana	20·68	13·90	17·29	23·23	11·47	17·35	17·32	+0·06
Port Rush	18·95	16·23	17·59	20·35	15·13	17·74	17·66	+0·15
Carrowkeel	20·00	15·87	17·94	21·66	14·72	18·19	18·06	+0·25
Ballycastle	18·39	16·48	17·44	19·17	16·21	17·69	17·56	+0·25
Glenarm	20·08	15·11	17·60	20·60	14·67	17·64	17·63	+0·04
Donaghadee	21·73	13·83	17·78	23·12	12·56	17·84	17·81	+0·06
Ardglass	22·54	12·64	17·59	24·64	10·68	17·66	17·62	+0·07
Clogher Head	21·85	12·30	17·08	23·91	10·28	17·10	17·09	+0·02
Kingstown	21·04	13·69	17·37	22·59	12·05	17·32	17·34	−0·05
Dunmore East	19·72	11·82	15·77	21·57	10·08	15·83	15·80	+0·06
New Ross	21·23	11·92	16·58	23·31	10·42	16·87	16·72	+0·29
Passage West	20·07	11·67	15·87	22·01	10·15	16·08	15·97	+0·21
Castle Townsend	18·90	12·22	15·56	20·44	10·87	15·66	15·61	+0·10

The column which first demands our attention is the "Mean of Apparent Mean Heights." The Apparent Mean Height increases in ascending the Shannon from Kilbaha to Limerick, and in ascending the Barrow from Dunmore East to New Ross. There is no difficulty in perceiving that such an effect must result from the mixture of a river-current with a tide, when the motion of the water is impeded by friction. But the Apparent Mean Height increases also from Kilbaha and Castle Townsend in going northward along both the eastern and the western coasts. And this occurs both at large tides and at small tides, with comparatively very little difference of amount. This conclusion will be fully supported by the results deduced by a more elaborate process from the whole mass of observations in Section XI. The details of levelling in the first section will scarcely permit us to ascribe any large part of this seeming difference of Apparent Mean Height to error in the instrumental process.

I regard this as a most important result, and I cannot with confidence offer any explanation of it.

The last column seems to show that the Apparent Mean Height is greater for large ranges of tide than for small ones, or that in spring tides the increase of elevation of the high water is greater than the increase of depression of the low water. A similar result has been found in the Thames. It does not appear to admit of explanation with our present theoretical knowledge. But in a period of two months it is impossible to separate the effects of varying range from those of varying declination of the moon and other varying circumstances.

For investigation of the effect of the moon's declination on the apparent mean height, the following process was used. It is to be remarked that (setting aside the differences of the moon's distance) the effect of southern declination is the same as that of northern declination; and the effect is proportional nearly to the square of declination; and therefore the groups into which our observations are to be divided are to be classified by large declinations (of either kind) and by small declinations; the separating time being nearly that at which the moon's declination $= \frac{1}{\sqrt{2}} \times$ moon's maximum declination. The times being thus found, one day was added to each, and thus the following separation of groups was made.

	d	h		d	h	
1st Group, June	26	3	to July	3	14,	small declination.
2nd Group, July	3	14	to July	10	2,	large declination.
3rd Group, July	10	2	to July	16	8,	small declination.
4th Group, July	16	8	to July	23	10,	large declination.
5th Group, July	23	10	to July	30	22,	small declination.
6th Group, July	30	22	to August	6	12,	large declination.
7th Group, August	6	12	to August	12	15,	small declination.
8th Group, August	12	15	to August	19	16,	large declination.

For each of these groups, the mean of the heights at high water was taken, and the mean of the heights at low water; and the mean of these gave a mean Apparent Mean Height in each group. The mean of the results from the 1st, 3rd, 5th and 7th groups, was used for small declinations, and the mean of the results from the 2nd, 4th, 6th and 8th, was used for large declinations. At Ballycastle the first group was wanting. Thus the following Table was found.

Station.	Apparent Mean Height with small declination.	Apparent Mean Height with large declination.	Excess of Apparent Mean Height with large declination above Apparent Mean Height with small declination.
	ft.	ft.	ft.
Kilbaha	15·64	15·66	+0·02
Kilrush	16·29	16·35	+0·06
Foynes Island .	16·71	16·81	+0·10
Limerick.....	16·70	16·79	+0·09
Casleh Bay....	17·94	18·00	+0·06
Galway	17·46	17·53	+0·07
Old Head	17·75	17·79	+0·04
Mullaghmore ..	18·05	18·13	+0·08
Buncrana	17·31	17·38	+0·07
Port Rush	17·64	17·70	+0·06
Carrowkeel....	17·98	18·11	+0·13
Ballycastle	17·51	17·60	+0·09
Glenarm.....	17·56	17·69	+0·13
Donaghadee ..	17·77	17·86	+0·09
Ardglass.....	17·59	17·70	+0·11
Clogher Head..	17·00	17·18	+0·18
Kingstown	17·26	17·45	+0·19
Dunmore East .	15·77	15·82	+0·05
New Ross	16·72	16·69	−0·03
Passage West..	15·99	15·93	−0·06
Castle Townsend	15·60	15·59	−0·01

In like manner, a series of groups was formed, determined by the increase or decrease of the moon's declination without regard to its sign; one day being added to each of the times when the moon's declination was 0, and when it was maximum either north or south. Thus the following separation of groups was made.

	d	h		d	h	
1st Group, June	22	11	to June	29	21,	declination decreasing.
2nd Group, June	29	21	to July	7	0,	declination increasing.
3rd Group, July	7	0	to July	13	3,	declination decreasing.
4th Group, July	13	3	to July	19	19,	declination increasing.
5th Group, July	19	19	to July	27	4,	declination decreasing.
6th Group, July	27	4	to August	3	9,	declination increasing.
7th Group, August	3	9	to August	9	12,	declination decreasing.
8th Group, August	9	12	to August	16	0,	declination increasing.
9th Group, August	16	0	to August	23	11,	declination decreasing.

The mean of results from the 1st, 3rd, 5th, 7th and 9th groups was used for decreasing declination, and that of results from the 2nd, 4th, 6th and 8th, for increasing declination. At the first six stations, and at Ballycastle and Passage West, the first group was deficient. Thus the following Table was formed.

Station.	Apparent Mean Height with decreasing declination.	Apparent Mean Height with increasing declination.	Excess of Apparent Mean Height with decreasing declination over Apparent Mean Height with increasing declination.
	ft.	ft.	ft.
Kilbaha	15·65	15·64	+0·01
Kilrush	16·37	16·27	+0·10
Foynes Island .	16·76	16·74	+0·02
Limerick.....	16·84	16·64	+0·20
Casleh Bay....	17·96	17·95	+0·01
Galway	17·50	17·47	+0·03
Old Head	17·85	17·37	+0·48
Mullaghmore ..	18·23	17·99	+0·24
Buncrana	17·47	17·27	+0·20
Port Rush	17·82	17·57	+0·25
Carrowkeel....	18·19	17·92	+0·27
Ballycastle	17·68	17·45	+0·23
Glenarm.....	17·73	17·59	+0·14
Donaghadee ..	17·91	17·77	+0·14
Ardglass.....	17·72	17·59	+0·13
Clogher Head..	17·17	17·05	+0·12
Kingstown	17·41	17·35	+0·06
Dunmore East .	15·87	15·76	+0·11
New Ross	16·85	16·61	+0·24
Passage West ..	16·05	15·89	+0·16
Castle Townsend	15·65	15·57	+0·08

It would seem from this that, if the apparent mean height depends upon the moon's declination, it is greatest when the moon's declination has decreased nearly to the point where the argument of declination is 135° or 315° (which makes the declination $=\frac{1}{\sqrt{2}}\times$ maximum declination). Thus at the middle of the observations, it is greatest about July 22. Now on July 22, the magnitude of the tide, though above the mean, was not maximum. From this circumstance, and from the decided superiority in magnitude of the excess found by classifying the tides by the moon's declination, over the excess found by classifying the tides by the magnitude of the tide, it appears extremely probable that the excess does really depend on the moon's declination. In that case, the greatest apparent mean height will occur about four days after the day of greatest declination.

Section VI.—*Discussion of the range of tide; and of semimenstrual inequality in height, apparent proportion of solar and lunar effects as shown by heights, and age of tide as shown by heights; from high waters and from low waters.*

The numbers from which we shall extract the results of this section are contained in the table of page 30. The means of the heights are made subservient to the accurate determinations of specific heights in the following manner. If θ is the difference of right ascension of the sun and moon, S and M their respective single effects, then (neglecting declinations, &c.) the actual height may be represented by $A+M\sqrt{\left\{1+\frac{2S}{M}\cos 2\theta+\frac{S^2}{M^2}\right\}}$. If we expand this and integrate from $\theta=-45°$ to

$\theta = +45°$, and divide by $\frac{\pi}{2}$, we obtain the expression for the mean of large tides. If we integrate from $\theta = 45°$ to $\theta = 135°$, and divide by $\frac{\pi}{2}$, we obtain the expression for the mean of small tides. The difference between these, which will be found to be $\frac{4}{\pi}S - \frac{2}{3\pi}\cdot\frac{S^3}{M^3}$, is the same as the difference between the second and fifth columns in the table of p. 30, if high water is under consideration, or as the difference between the third and sixth columns, if low water is under consideration, or as the difference between the 2nd column $-$3rd, and 5th column $-$6th, if the range is considered. The second term of the formula may sometimes be omitted: and then we have $\frac{4}{\pi}S =$ difference, and $S = \frac{\pi}{4} \times$ difference, S being the solar effect in the elevation or range under consideration. If we add this to the mean elevation, which is represented by A+M nearly, we shall have A+M+S which is the absolute maximum; and if we subtract it, we have A+M$-$S, which is the absolute minimum. The same applies to range, with this difference only, that the constant A will be eliminated in subtracting the heights at low water from those at high water.

In order to obtain the value of $\frac{S}{M}$, we may remark that the difference of the two means divided by half the sum is $\dfrac{4\frac{S}{M} - \frac{2}{3}\frac{S^3}{M^3}}{\pi\left(1 + \frac{1}{4}\frac{S^2}{M^2}\right)}$; and if we call this δ, we easily find $\frac{S}{M} = \frac{\pi}{4}\delta\left\{1 + \frac{5}{12}\left(\frac{\pi}{4}\delta\right)^2\right\}$, in which the last term is small.

Neither of these expressions is perfectly correct, because they assume that the tidal day is always of the same length.

By means of these formulæ, and the numbers on page 30, the following Table is formed.

Station.	Difference of mean heights in large tides and in small tides.		Proportion of difference at high water to difference at low water.	Range in mean of large tides.	Range in mean of small tides.	Difference.	Mean range, or M.	Difference divided by mean range.	Corresponding value of $\frac{S}{M}$.	Absolute maximum range.	Absolute minimum range.	Half difference, or S.
	High water.	Low water.										
	ft.	ft.	ft.	ft.	ft.	ft.	ft.			ft.	ft.	ft.
Kilbaha	2·45	2·35	1·04	12·22	7·42	4·80	9·82	0·49	0·41	13·8	5·8	4·0
Kilrush	2·46	2·29	1·07	13·19	8·44	4·75	10·82	0·44	0·36	14·7	6·9	3·9
Foynes Island	2·57	2·55	1·01	15·26	10·14	5·12	12·70	0·40	0·33	16·9	8·5	4·2
Limerick	3·16	2·59	1·22	18·98	13·23	5·75	16·11	0·36	0·29	20·8	11·4	4·7
Casleh Bay	2·62	2·60	1·01	12·91	7·69	5·22	10·30	0·51	0·43	14·7	5·9	4·4
Galway	2·80	2·72	1·03	13·64	8·12	5·52	10·88	0·51	0·43	15·6	6·1	4·7
Old Head	2·42	2·24	1·08	11·56	6·90	4·66	9·23	0·50	0·42	13·1	5·3	3·9
Mullaghmore	2·20	1·86	1·18	10·50	6·44	4·06	8·47	0·48	0·40	11·9	5·1	3·4
Buncrana	2·55	2·43	1·05	11·76	6·78	4·98	9·27	0·54	0·46	13·6	5·0	4·3
Port Rush	1·40	1·10	1·27	5·22	2·72	2·50	3·97	0·63	0·55	6·0	1·8	2·2
Carrowkeel	1·66	1·15	1·44	6·94	4·13	2·81	5·54	0·51	0·43	7·9	3·1	2·4
Ballycastle	0·78	0·27	2·90	2·96	1·91	1·05	2·44	0·43	0·36	3·3	1·5	0·9
Glenarm	0·52	0·44	1·18	5·93	4·97	0·96	5·45	0·18	0·14	6·2	4·7	0·8
Donaghadee	1·39	1·27	1·10	10·56	7·90	2·66	9·23	0·29	0·23	11·3	7·1	2·1
Ardglass	2·10	1·96	1·07	13·96	9·90	4·06	11·93	0·34	0·27	15·1	8·7	3·2
Clogher Head	2·06	2·02	1·02	13·63	9·55	4·08	11·59	0·35	0·28	14·8	8·4	3·2
Kingstown	1·55	1·64	0·95	10·54	7·35	3·19	8·95	0·36	0·29	11·6	6·4	2·6
Dunmore East	1·85	1·74	1·06	11·49	7·90	3·59	9·70	0·37	0·30	12·6	6·8	2·9
New Ross	2·08	1·50	1·39	12·89	9·31	3·58	11·10	0·32	0·26	14·0	8·2	2·9
Passage West	1·94	1·52	1·28	11·86	8·40	3·46	10·13	0·34	0·27	12·8	7·4	2·7
Castle Townsend	1·54	1·35	1·14	9·57	6·68	2·89	8·13	0·36	0·29	10·5	5·7	2·4

The numbers in this table present several subjects for our consideration.

First, it is to be remarked that the difference between the numbers of the second and third columns corresponds to the number in the last column of the table on page 30 (it is, in fact, the double of that number); but the exhibition of the numbers in this form serves, in some instances, to point out their origin more distinctly. At Limerick, for instance, it appears that a large tide produces less effect on the low water than on the high water; and the reason evidently is, that the height of low water there depends more upon the freshwater current of the river Shannon, than upon the state of the water in the sea, whereas the height of high water depends mainly on the sea. The same explanation applies at New Ross and at Passage West. It does not however apply to Mullaghmore, Port Rush, Ballycastle, or Glenarm; nor, with perfect certainty, to Carrowkeel. I must refer to Section X. and some of the succeeding sections, for a statement of the laws of the individual tides at these places; and shall only remark here, that much remains to be done with the theoretical treatment of the motion of waves, before the tides on the north-eastern coast can be fully explained.

The next column which deserves particular attention is that for $\frac{S}{M}$. From the agreement among the numbers at the littoral stations on the western coast (Kilbaha, Casleh Bay, Galway, Old Head, Mullaghmore), it seems certain that the value of $\frac{S}{M}$, in this part of the Atlantic, is pretty exactly 0·42. At Brest, in a position equally

exposed to the open sea, LAPLACE found $\frac{S}{M}=0{\cdot}33$. I imagine that, as regards the sun's position in declination, the present series of tides may be supposed to give a value for $\frac{S}{M}$ differing very little from the mean, but rather too small than too great. If so, here is an undoubted discordance. Yet it is remarkable that the series of numbers in this table presents a still greater discordance under circumstances where we should hardly expect it. The littoral station of Castle Townsend is fully open to the Atlantic; and those of Dunmore East, Kingstown, and Clogher Head, are more and more subject to the effects (whatever they may be) of the inclosure of the Irish Channel. Yet all these stations, including Castle Townsend, give for $\frac{S}{M}$ a value of about 0·28.

In speculating on the causes of these discordances, it is important to observe, that the relation of the successive changes of a progressive tide may be considered in two different ways. One of these ways is applicable properly to rivers and similar channels; it consists in assuming that each semidiurnal tide is nearly independent of every other semidiurnal tide, and that the quantities of the second and higher orders of the range are sensible*. The other is applicable to open seas, where the vertical oscillation is insignificant in comparison with the depth, and where the alteration of the horizontal surface, by the shoaling of the shore, is perfectly unimportant; here the principle of the superposition of small movements applies, and the solar and lunar tides may be considered as perfectly independent. Thus considered, the discordance to which I have alluded may be stated thus: the lunar tide at Castle Townsend is less than that at Kilbaha, in the proportion of 8·13 to 9·82, but the solar tide at Castle Townsend is less than that at Kilbaha, in the proportion of 2·4 to 4·0. There can be no doubt that in the lunar tide, the difference between 8·13 and 9·82 depends (among other circumstances) upon the periodic time of the tide, inasmuch as a tide infinitely slow would produce the same effect at both stations; and therefore we must not be surprised that the solar tide, whose recurrence is more rapid than that of the lunar tide, should undergo a larger proportional alteration, like that between 2·4 and 4·0.

In another section I shall show that between Dunmore East and Kingstown, the tide is suddenly and completely reversed, high water at one of these stations corresponding exactly (in time) to low water at the other; while from Dunmore East to Donaghadee, there is scarcely any perceptible difference of phase. It is worthy of remark, that during these changes and coincidences, the value of $\frac{S}{M}$ is unaltered.

The remarkable change in the values of $\frac{S}{M}$ at Port Rush, Ballycastle, and Glenarm, depends also, without doubt, upon the difference of the modifications produced in the

* Encyclopædia Metropolitana, *Tides and Waves*, Section IV., Subsection 3.

solar and in the lunar tides, by the narrow channel which, beginning with Islay (opposite Port Rush), continues to the Mull of Galloway (opposite Donaghadee). But I profess myself totally unable to explain with greater accuracy why, in passing from Mullaghmore to Ballycastle, the principal reduction of lunar tide takes place between Mullaghmore and Port Rush, while the principal reduction of solar tide takes place between Port Rush and Ballycastle.

The successive diminution in the values of $\frac{S}{M}$ from Kilbaha to Kilrush, Foynes Island, and Limerick, as well as the reduction from Dunmore East to New Ross, and that from Port Rush to Buncrana and Carrowkeel, are to be explained from the other consideration which I have described as applicable to rivers In fact, in these cases, from the very greatly contracted current-way at low water, the effect of variation in the depression of the ocean low water is very small, and therefore the effect of semi-menstrual inequality is sensible almost only in the high water, and its whole effect on the range is therefore less than it ought to be.

Before dismissing this table, I shall remark, that the very great diminution in the range of tide in the North Channel, makes it impossible for us to believe that the tide in the Irish Channel is supplied from the North Channel, however much the consideration of the times in the next section may lead us, in the first instance, to imagine so.

I will now proceed with the age of the tide as shown by the heights. The method employed was the following:—

The mean heights having been found from the preceding tables, the heights for every day (corrected for diurnal tide) were examined, and the time was ascertained as nearly as practicable at which the height coincided with the mean height. These times were then compared with the times at which the moon's hour-angle from the sun was 3^h, 9^h, 15^h, and 21^h; namely, June, $26^d\ 6^h$; July, $4^d\ 16^h$, $11^d\ 3^h$, $18^d\ 9^h$, $26^d\ 9^h$; August, $3^d\ 0^h$, $9^d\ 16^h$, $16^d\ 15^h$. High waters and low waters were treated separately. At each place eight comparisons were obtained for high water and eight for low water: excepting that in the high waters, no comparison was made at Old Head with July $11^d\ 3^h$, and $18^d\ 9^h$ (the times of mean height being very uncertain); nor at Ballycastle, with July $18^d\ 9^h$ and $26^d\ 9^h$ (for the same reason), nor with June $26^d\ 6^h$ (the observations having commenced too late); nor at Glenarm, Donaghadee, or Kingstown, with July $18^d\ 9^h$ and $26^d\ 9^h$ (the times being uncertain). The results for each place being collected, and the means being taken, the following Table was formed:—

Age of Tide as inferred from Heights.

Station.	High water.	Low water.	Station.	High water.	Low water.
	d h	d h		d h	d h
Kilbaha	2 2	2 0	Ballycastle	2 2	2 17
Kilrush	1 21	2 3	Glenarm.....	1 7	2 6
Foynes Island....	2 2	2 4	Donaghadee ...	1 19	2 17
Limerick.....	2 2	2 7	Ardglass.....	2 5	2 11
Casleh Bay.....	2 0	2 2	Clogher Head....	2 4	3 4
Galway	2 2	2 2	Kingstown	1 20	2 13
Old Head	1 15	2 6	Dunmore East ..	2 1	2 14
Mullaghmore....	1 22	2 8	New Ross	2 2	2 14
Buncrana	2 1	2 5	Passage West....	1 21	2 7
Port Rush	1 17	2 5	Castle Townsend .	1 21	2 9
Carrowkeel.....	1 17	2 6			

In the Encyclopædia Metropolitana, *Tides and Waves*, Art. 545, I have given reasons for believing that the true age of the tide is that given by the heights. From the inspection of this table it appears certain that the age of the tide on the western coast of Ireland is almost exactly two days. The different results are upon the whole very consistent. Yet there are some discordances which I cannot entirely explain. The most distinctly marked discordance is this—that the age given by the Low Waters is, in every instance except one, greater than that given by the High Waters. I have shown, I think, with certainty, in the Encyclopædia Metropolitana, *Tides and Waves*, Articles 452 and 544, that the cause of the principal part of the apparent age of tide is friction. It appears to me not unlikely, that, on carrying out the theory of friction in combination with the consideration of oscillations bearing a finite proportion to the depth of the sea, the apparent age of the tide might be found greater for low waters than for high waters. But I have not examined the theory so far as to feel myself warranted in positively assigning this as the explanation.

Section VII.—*Establishment of each port, and progress of semidiurnal tide round the island.*

The process used in this investigation is very nearly similar to that by which the table in page 30 was formed. The mean interval from the moon's transit at Greenwich to the time of tide was found (by the operations of the next section) to coincide with the actual interval nearly at the following times:—Port Rush and Ballycastle (high and low), June, $22^d\ 9^h$, $30^d\ 20^h$; July, $7^d\ 19^h$, $14^d\ 21^h$, $21^d\ 23^h$, $30^d\ 16^h$; August, $6^d\ 4^h$, $13^d\ 5^h$, $20^d\ 16^h$: Kilbaha, Kilrush, Casleh Bay, Galway, Mullaghmore, Buncrana, Carrowkeel, Glenarm, Donaghadee, Ardglass, Clogher Head, Kingstown, Castle Townsend, (high and low), $1^d\ 8^h$ later; Foynes Island, Old Head, Dunmore East, Passage West (high and low), Limerick (high only), 20^h later than the last; New Ross (high and low), 23^h later than the last; Limerick (low only), 22^h later than the last, or $4^d\ 1^h$ later than at Port Rush and Ballycastle. The intervals from the moon's transit to the time of tide being taken for every tide (the high water, 1st division, being referred to the upper transit, the low water, 1st division, to the transit over the

meridian 6^h west, the high water, 2nd division, to the lower transit, and the low water, 2nd division, to the transit over the meridian 18^h west), groups were formed divided by the times above mentioned, and the mean of the intervals was taken for each group. Thus the following Table was formed:—

Station.	High water.			Low water.			Mean of both.
	Mean of large intervals.	Mean of small intervals.	Mean.	Mean of large intervals.	Mean of small intervals.	Mean.	
	h m	h m	h m	h m	h m	h m	h m
Kilbaha	5 11	4 23	4 47	5 6	4 12	4 39	4 43
Kilrush	5 22	4 31	4 56	5 20	4 28	4 54	4 55
Foynes Island	6 15	5 30	5 52	6 0	5 12	5 36	5 44
Limerick	6 46	6 0	6 23	7 14	6 17	6 45	6 34
Casleh Bay	5 21	4 30	4 55	5 11	4 14	4 42	4 48
Galway	5 28	4 40	5 4	5 11	4 13	4 42	4 53
Old Head	5 22	4 47	5 4	5 22	4 45	5 3	5 4
Mullaghmore	6 2	5 9	5 35	5 53	5 7	5 30	5 33
Buncrana	6 45	5 39	6 12	6 34	5 36	6 5	6 8
Port Rush	7 29	6 0	6 45	7 14	5 59	6 36	6 40
Carrowkeel	8 11	7 2	7 36	8 1	7 4	7 32	7 34
Ballycastle	8 37	6 14	7 25	8 47	7 3	7 55	7 40
Glenarm	11 1	10 26	10 43	11 7	10 22	10 44	10 44
Donaghadee	11 21	10 42	11 1	11 23	10 36	11 0	11 1
Ardglass	11 21	10 40	11 0	11 25	10 38	11 2	11 1
Clogher Head	11 41	10 54	11 17	11 34	10 47	11 10	11 14
Kingstown	11 52	11 6	11 29	11 29	10 41	11 5	11 17
Dunmore East	5 32	4 47	5 9	5 41	4 56	5 18	5 13
New Ross	6 17	5 36	5 56	6 55	6 9	6 32	6 14
Passage West	5 38	4 55	5 16	5 52	5 9	5 30	5 23
Castle Townsend	5 16	4 29	4 52	5 19	4 30	4 54	4 53

On inspecting the intervals for Castle Townsend, Kilbaha, Casleh Bay, Galway, Old Head, and Mullaghmore, it appears evident that the semidiurnal tide approaches the western coast of Ireland very nearly from the west, or possibly from a direction a little south of the west. On examining the intervals at Port Rush, Ballycastle, Glenarm, Donaghadee, their regular progression seems at first to show that the tide wave enters the Irish Sea by way of the North Channel. But the objections to this supposition are most serious. Theoretically it is certain that (even without regarding the effects of friction) when a tide-wave passing through a narrow channel enters into a wide one its vertical range will be diminished*. But here the mean range in the narrow channel at Ballycastle is only $2\frac{1}{2}$ feet and at Glenarm $5\frac{1}{2}$ feet: this tide-wave therefore could not possibly produce a tide of more than one or two feet in the Irish Sea; whereas, from Ardglass southward to Kingstown, the range is from ten to twelve feet. It seems therefore that this supposition may at once be dismissed; and the only supposition which can be substituted for it is, that the tide-wave enters the Irish Sea by St. George's Channel. But here a most remarkable circumstance occurs. A reference to the table above will show that the high water at Kingstown occurs six hours and a few minutes later than that at Dunmore East, or, in other words, that

* Encyclopædia Metropolitana, *Tides and Waves*, Art. 264.

the high water at Kingstown coincides *precisely* with the low water at Dunmore East, and *vice versâ*. Moreover, between these two stations occurs the station Courtown; and here, as will appear in Section XVII., the semidiurnal tide is nearly insensible. The difference in the times at Dunmore East and Kingstown does not therefore arise from a slow transmission of tide; but arises from a sudden *inversion* of the wave, the point which separates elevation from depression being not far from Courtown. And the question now is, whether, on the supposition that the tide-wave enters the Irish Sea by this southern entrance, it is possible to explain the existence of this neutral point and the inversion of the tide beyond it.

The explanation which I have to give rests upon a proposition long known to me as a matter of theory, but for which I never expected to find a practical application. In the Encyclopædia Metropolitana, *Tides and Waves*, Art. 307, I have shown that when the tidal wave enters a gulf (considered as a canal of uniform breadth and depth, stopped by a transverse barrier), the expression for the elevation of the water at the time t at a point whose distance from the sea is x, is $\frac{A}{\cos ma}\sin nt+B\cos \overline{ma-mx}$; where n is the constant proper to the periodic time of the tide-wave, $\frac{n}{m}=\sqrt{g\times \text{depth}}$, and a is the whole length of the canal. This expression shows that the vertical oscillations are simultaneous throughout; the coefficient in each place being $\frac{A}{\cos ma}\cos \overline{ma-mx}$. Now if the canal is so long and so shallow that ma is greater than $\frac{\pi}{2}$; then, on taking $x=a-\frac{\pi}{2m}$ the coefficient vanishes; and on taking x greater than $a-\frac{\pi}{2m}$ the coefficient changes its sign. This case then agrees, as regards the simultaneity and the inversion, with the case of observation before us, and all that is necessary for its complete application is, that the virtual head of the channel be supposed to be at a distance from Courtown equal to that which a *progressive* wave would pass over in $3^h\ 5^m$ $\left(\text{which would make } ma=\frac{\pi}{2}\right)$. Without professing myself able to enter into details upon the depth of the water and the form of the supposed channel, I express my belief that this solution does accurately apply here: and I regard it as one of the most remarkable cases that has ever been noticed in the observations of tides.

Assuming then that the tide of the Irish Sea is explained, we have only further to explain the apparent passage of the tide through the North Channel. This is merely a case of the proposition in Art. 310 of the *Tides and Waves*, relating to a canal joining two tidal seas, from which it appears that there will always be in such a canal an apparent passage of the tide-wave in the same direction at every part. To represent the circumstances completely, it would be necessary to introduce the consideration of friction.

The only remaining result of the table in page 39 which deserves attention here, is the difference of the times occupied by the rise of the water and by the fall of the water. In the river stations (Limerick and New Ross) the fall of the water occupies a longer time than the rise. This, as a consequence of theory, is explained in Art. 206 of the *Tides and Waves*. At most of the other stations, the rise appears to occupy a very little longer time than the fall. This, however, as it depends on the estimation of the times of high and low water, is subject to great doubt: the terms upon which such difference depends will be investigated with great accuracy in Sections X. and XVI.

Section VIII.—*Semimenstrual inequality in time, proportion of solar and lunar effects as shown by times, and apparent age of tide as shown by times; from high water and from low water.*

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The interval from the moon's transit over the meridian to high water (and similarly from the moon's transit over the six-hour meridian to low water) is theoretically expressed by $E+F$, where E is a constant, and $\tan 2F=\frac{\frac{S}{M}\sin 2\theta}{1+\frac{S}{M}\cos 2\theta}$, θ being the hour-angle of the moon from the sun. The declinations, &c. are supposed here to have their mean values. Investigating from this the expression for F, integrating from $\theta=0$ to $\theta=\frac{\pi}{2}$, and dividing by $\frac{\pi}{2}$, we obtain the value of the mean of large intervals; performing the same operation from $\theta=\frac{\pi}{2}$ to $\theta=\pi$, we obtain the value of the mean of small intervals. The difference which will be found $=\frac{2}{\pi}\cdot\frac{S}{M}\left(1+\frac{1}{9}\left(\frac{S}{M}\right)^2\right)$, is the difference between the 2nd and 3rd columns or between the 5th and 6th columns in page 39, expressed in arc; or, as 2π of arc in the estimation of θ and F correspond to a tidal day of 1488^m, if we put i for the number of minutes in that difference, the equation is

$$\frac{2}{\pi}\cdot\frac{S}{M}\left(1+\frac{1}{9}\cdot\left(\frac{S}{M}\right)^2\right)=i\times\frac{2\pi}{1488}.$$

From this we obtain

$$\frac{S}{M}=\frac{\pi^2.i}{1488}\times\left\{1-\frac{1}{9}\cdot\left(\frac{\pi^2 i}{1488}\right)^2\right\}\text{ nearly};$$

and then the maximum value of F in arc will be found by making $\sin 2F=\frac{S}{M}$, and converting F into time by the proportion stated above. Thus the following Table is formed.

Station.	High water.			Low water.			Mean of values of $\frac{S}{M}$.
	Difference of means of large intervals and small intervals.	Value of $\frac{S}{M}$.	Maximum semimenstrual inequality ±.	Difference of means of large intervals and small intervals.	Value of $\frac{S}{M}$.	Maximum semimenstrual inequality ±.	
	m		m	m			
Kilbaha	48	0·32	38·5	54	0·35	42	0·34
Kilrush	51	0·34	41	52	0·34	41	0·34
Foynes Island	45	0·30	36	48	0·32	38·5	0·31
Limerick	46	0·31	37	62	0·40	48·5	0·35
Casleh Bay	51	0·34	41	57	0·37	44·5	0·36
Galway	48	0·32	38·5	58	0·37	44·5	0·34
Old Head	35	0·23	27	37	0·24	28·5	0·24
Mullaghmore	53	0·35	42	46	0·31	37	0·33
Buncrana	66	0·42	51	58	0·37	44·5	0·39
Port Rush	89	0·57	71·5	75	0·49	60	0·53
Carrowkeel	69	0·45	54·5	57	0·37	44·5	0·41
Ballycastle	143	0·82	113	104	0·65	83	0·74
Glenarm	35	0·23	27	45	0·30	36	0·26
Donaghadee	39	0·25	30	47	0·31	37	0·28
Ardglass	41	0·27	32	47	0·31	37	0·29
Clogher Head	47	0·31	37	47	0·31	37	0·31
Kingstown	46	0·31	37	48	0·32	38·5	0·31
Dunmore East	45	0·30	36	47	0·31	37	0·31
New Ross	41	0·27	32	46	0·31	37	0·29
Passage West	43	0·28	33·5	43	0·28	33·5	0·28
Castle Townsend	47	0·31	37	49	0·33	39·5	0·32

I have stated in the Encyclopædia Metropolitana, *Tides and Waves*, Art. 538, that I consider the values of $\frac{S}{M}$ deduced from the semimenstrual inequalities in time to be real and certain representations of the proportions of the sun's effect to the moon's effect in the seas in the neighbourhood of each station; those deduced from the heights being liable to the effects of many local disturbing causes which do not affect those deduced from the times. In this view the table above deserves consideration. The littoral stations (including those in the Irish Sea) agree in giving a value of 0·32 or 0·33, nearly the same as that found at Brest by Laplace and Sir J. W. Lubbock. But at Port Rush and Ballycastle (the first stations in the North Channel) the lunar tide appears to be diminished in a far greater proportion than the solar tide. And then, after this alteration of relative magnitude has been established in the open sea of the neighbourhood, it appears to be again nearly destroyed by some local cause affecting the heights, so that in the table of page 35, the value of $\frac{S}{M}$ is restored to its average value. As far as the observations can be trusted for accuracy, the two conclusions which I have mentioned appear at first sight perfectly certain; for the greatest difference of intervals from moon's transit (on which the value of $\frac{S}{M}$ in this page depends) is deduced from comparisons of the times of tides of equal vertical range, in which therefore the stream of tide in the neighbouring channels of small depth and width, &c. was the same, and therefore could not disturb the difference of times.

But the value in page 35 is deduced from the comparison of high and low tides, in which the stream of tides, &c. is different. The second apparent alteration can take place only where the tide has arrived at such localities that the second order of the vertical oscillation produces sensible terms. I was at first misled by the plausibility of this reasoning.

Its fallacy, or rather its error, will appear from the following considerations. The semimenstrual inequality in time which theoretically is proper for giving the value of $\frac{S}{M}$ is that which depends only upon those differences of time which are caused by difference in the relative positions of the sun and moon, when the magnitudes of the tides are exactly the same. But when there also exists a difference of time caused by the difference of magnitude of the tide (having its maximum nearly at the time of evanescence of the proper semimenstrual inequality), then these two differences or inequalities are combined, forming a single inequality whose time of evanescence is different from those of both the original inequalities, and whose magnitude is greater than the magnitude of either. Thus it appears that the gross semimenstrual inequality in time must not be used for estimation of $\frac{S}{M}$. A correct application of these principles, and a consequent harmony of results, will be seen in Section XIV.

At every station except Mullaghmore, the value of $\frac{S}{M}$ in the table above appears greater at low water than at high water. This evidently depends upon the difference in times (as affected by magnitude of tide) for low water and for high water, which is combined as above stated with the proper semimenstrual inequality.

Mr. Whewell, in his invaluable memoirs on cotidal lines, stated that there were great contradictions in the accounts of the establishment of Ballycastle. The numbers above serve in some degree to explain this. The semimenstrual inequality alone, comparing observations taken when its value was maximum positive with those taken when its value was maximum negative, would produce nearly four hours of uncertainty. More than half an hour (see the table in page 19) might be added by the diurnal tide.

I shall now proceed with the age of tide as shown by the times. The method employed was the same as for the heights, in forming the table in page 38. The times were ascertained at which the interval from moon's transit over the meridian to high water (and similarly the interval from moon's transit over the 6-hour meridian to low water), corrected for diurnal tide, agreed with the mean interval for high water (or for low water) in page 39. These times were then compared with the times at which the moon's hour-angle from the sun was 0^h, 6^h, 12^h, 18^h; namely, June, $22^d\ 9^h$, $30^d\ 20^h$; July, $7^d\ 19^h$, $14^d\ 21^h$, $21^d\ 23^h$, $30^d\ 16^h$; August, $6^d\ 4^h$, $13^d\ 5^h$, $20^d\ 16^h$. The high and low waters were treated separately. At Ballycastle low water six results only were obtained; for all the other determinations seven or eight results were compared. Thus the following Table was formed.

Age of Tide as inferred from Times.

Station.	High water.	Low water.	Station.	High water.	Low water.
	d h	d h		d h	d h
Kilbaha	1 8	1 5	Ballycastle	−0 11	−0 19
Kilrush	1 13	1 10	Glenarm	+1 14	1 9
Foynes Island....	1 21	2 2	Donaghadee	1 7	1 9
Limerick.....	1 22	4 1	Ardglass.....	1 8	1 15
Casleh Bay.....	1 14	0 22	Clogher Head....	1 10	1 12
Galway	1 10	1 7	Kingstown	0 22	0 23
Old Head	2 10	2 9	Dunmore East ..	2 11	2 8
Mullaghmore	1 6	1 11	New Ross	2 20	3 11
Buncrana	1 4	1 3	Passage West....	2 2	1 19
Port Rush	0 4	0 7	Castle Townsend..	1 12	1 6
Carrowkeel.....	1 0	1 1			

In the *Tides and Waves*, Art. 463 and 465, I have shown that the age of tide inferred from the times of high water in a river (where spring-tide high waters pass more rapidly than neap-tide high waters) is too small, and that the age of tide inferred from the times of low water in a river (where spring-tide low waters pass more slowly than neap-tide low waters) is too great. These propositions, at least the second, are well illustrated at Limerick and New Ross. For the other stations I feel myself in some difficulty. With the exception only of Old Head, Dunmore East, and Passage West, all the ages of tide above are too small, for low water as well as for high water. This requires us to assume that all the phases of the tide-wave (low water as well as high water) are transmitted over the sea more rapidly in the spring-tides than in the neap-tides. I conjecture that some theory of friction may possibly explain this. It cannot be explained by supposing the second power of the small movements sensible; for on that assumption the age of tide given by low water would be increased.

It is worthy of remark that at Ballycastle the effects depending on the position of the sun and moon *appear* to precede their cause.

Section IX.—*Formation of the time of diurnal high water; progress of the diurnal tide-wave round the island; comparison of its progress and range with those of the semidiurnal tide.*

In page 20 I have given a table of the maximum values of diurnal tide, at high water and at low water. The diurnal tide being supposed to follow the law of sines, its maximum coefficient will be found by taking the square root of the sum of the squares of those two values, and the time after semidiurnal high water at which diurnal high water occurs will be found by taking the angle whose tangent $= \frac{\text{value at low water}}{\text{value at high water}}$, and converting that angle into time at the rate of 360° for a lunar day. The maximum diurnal tide for semidiurnal high water and that for semidiurnal low water may be conceived to hold for any day near to the day of absolute maximum. Thus the following Table is formed.

Station.	July 9.		July 23.		August 6.	
	Coefficient of diurnal tide.	Interval from semidiurnal high water, first division, to diurnal high water.	Coefficient of diurnal tide.	Interval from semidiurnal high water, first division, to diurnal high water.	Coefficient of diurnal tide.	Interval from semidiurnal high water, first division, to diurnal high water.
	ft.	h m	ft.	h m	ft.	h m
Kilbaha	0·55	20 44	0·71	9 5	0·38	20 36
Kilrush	0·56	20 4	0·57	9 0	0·53	20 25
Foynes Island	0·81	20 9	0·69	8 14	0·67	20 31
Limerick	1·01	19 50	0·69	9 11	0·64	20 50
Casleh Bay	0·69	20 12	0·66	8 44	0·63	20 28
Galway	0·81	19 49	0·71	8 37	0·43	20 55
Old Head	0·83	20 56	0·85	9 18	0·98	21 18
Mullaghmore	0·89	23 25	0·82	11 34	0·86	24 18
Buncrana	0·64	0 19	0·76	13 4	0·70	1 26
Port Rush	0·52	1 5	0·63	14 2	0·69	2 4
Carrowkeel	0·47	1 28	0·95	13 1	0·68	1 58
Ballycastle	0·50	0 24	0·68	13 11	0·60	1 4
Glenarm	0·96	22 8	0·79	10 3	0·99	22 19
Donaghadee	0·91	21 44	0·85	10 16	1·03	21 40
Ardglass	0·82	21 34	0·84	10 23	0·91	21 55
Clogher Head	0·85	22 2	0·79	10 21	0·83	21 42
Kingstown	0·76	21 38	0·67	10 3	0·83	21 58
Dunmore East	0·21	2 37	0·33	15 10	0·27	1 38
New Ross	0·22	0 51	0·40	14 33	0·25	0 47
Passage West	0·15	4 2	0·22	14 13	0·17	1 20
Castle Townsend	0·16	18 3	0·09	12 41	0·10	20 52

A glance at this table will show how different are the velocities of the diurnal tide-wave and the semidiurnal tide-wave. From Kilbaha to Port Rush, the diurnal tide travels in a direction so different, or with a velocity so small, that it loses $5\frac{1}{2}$ hours in time upon the semidiurnal wave. But it passes through the North Channel with such speed that at Donaghadee it has regained about $4\frac{1}{2}$ hours. Its course however will be better understood by forming the actual time of high diurnal tide, or rather its interval after the moon's transit. I have treated the numbers in the following manner:—Increasing the numbers for July 23rd by $12^h\ 24^m$, or half a tidal day (because the moon's declination then was in a direction opposite to that on July 9th and August 6th), I have three comparable intervals from semidiurnal high water to diurnal high water. I take the mean of these, and apply it to the mean interval from moon's transit to semidiurnal high water in the table of page 39. I also take the mean of the three coefficients. Thus the following Table is formed; in which it is to be remembered that the coefficients are to be taken positive for July 9th and August 6th, and negative for July 23rd.

Station.	Coefficient of diurnal tide.	Interval from moon's transit to diurnal high water.	Station.	Coefficient of diurnal tide.	Interval from moon's transit to diurnal high water.
	ft.	h m		ft.	h m
Kilbaha	0·61	0 51	Ballycastle	0·59	8 25
Kilrush	0·55	0 45	Glenarm.....	0·91	8 15
Foynes Island....	0·72	1 22	Donaghadee	0·93	8 14
Limerick.....	0·78	2 31	Ardglass.....	0·86	8 18
Casleh Bay.....	0·66	0 38	Clogher Head....	0·82	8 36
Galway	0·65	0 40	Kingstown	0·75	8 30
Old Head	0·89	1 35	Dunmore East ..	0·27	7 33
Mullaghmore....	0·86	4 39	New Ross	0·29	7 30
Buncrana	0·70	6 56	Passage West....	0·18	7 47
Port Rush	0·61	8 16	Castle Townsend..	0·12	1 25
Carrowkeel.....	0·70	8 55			

Comparing the coefficients in this table with the column of mean range of semidiurnal tide in page 35, we can discover no analogy between them. The range of diurnal tide is not at all reduced in the North Channel, where the semidiurnal tide is so much diminished; nor (as will also be shown hereafter) is it particularly diminished between Kingstown and Dunmore East, where the semidiurnal tide is nearly or quite obliterated; but it is much diminished at Castle Townsend, where the semidiurnal tide is pretty large.

On examining the interval from moon's transit, it appears evident that the diurnal tide comes from the south, or very nearly from the south. It appears also that it does not pass in either direction through the North Channel, but that the strait is filled simultaneously, or nearly so, at both ends. It appears also that the wave travels very quickly from south to north in the Irish Channel; so quickly indeed that it is probable that the tide is simultaneous throughout. But between Castle Townsend and Passage West it loses more than six hours, or a quarter of a diurnal tide. I am totally unable to explain this. The case is very greatly different from that discussed in page 40, where the change of phase was almost exactly half a tide. I must leave the solution of this difficulty to some more advanced theory of waves.

I may appropriately close this section with a statement, in the form commonly used by nautical persons, of the most prominent effects of the diurnal tide at the several stations.

Assuming that the maximum diurnal tide, with positive sign for the semidiurnal high waters 1st division, occurred about July 9 and August 6, and with opposite sign on July 23, it appears that the maximum takes place when the moon's right ascension is about 9^h. This is not very accurate; first, because the solar diurnal tide is neglected; secondly, because the days adopted are not purely for maximum at semidiurnal high water, but partly also refer to low water. Using however 9^h, it appears from the table in page 39, that the semidiurnal high water at Kilbaha follows the moon's Greenwich transit by $4^h\ 47^m$; and, therefore, when the diurnal tide is greatest, the semidiurnal tide at Kilbaha occurs at $13^h\ 47^m$ Greenwich sidereal time, or $13^h\ 7^m$ Kilbaha sidereal time. If this happens at noon, the sun's right ascension

must be $13^h\ 7^m$, or the day must be about October 12; if it happens at six in the morning, the sun's right ascension must be $19^h\ 7^m$, and the day must be about January 6. In the same way the day may be found for other hours. The coefficient may be taken from the table in page 28, doubling the mean of the quantities in the three high water columns (without regard of sign) for the difference of two tides. Thus the following Table is formed.

Station.	Greatest difference of two high waters on same day.	Day when the excess of noon tide over mid-night tide is greatest.	Day when the excess of morning tide over evening tide is greatest.	Station.	Greatest difference of two high waters on same day.	Day when the excess of noon tide over mid-night tide is greatest.	Day when the excess of morning tide over evening tide is greatest.
	ft.				ft.		
Kilbaha	0·71	Oct. 12.	Jan. 6.	Ballycastle	1·16	Nov. 24.	Feb. 16.
Kilrush	0·55	Oct. 14.	Jan. 8.	Glenarm	1·48	Jan. 7.	April 10.
Foynes Island ..	0·72	Oct. 30.	Jan. 22.	Donaghadee	1·41	Jan. 13.	April 17.
Limerick.....	0·77	Nov. 7.	Jan. 30.	Ardglass.....	1·32	Jan. 13.	April 17.
Casleh Bay.....	0·65	Oct. 14.	Jan. 8.	Clogher Head....	1·29	Jan. 16.	April 20.
Galway	0·61	Oct. 17.	Jan. 10.	Kingstown	1·16	Jan. 19.	April 23.
Old Head	1·14	Oct. 17.	Jan. 10.	Dunmore East ..	0·44	Oct. 21.	Jan. 5.
Mullaghmore	1·65	Oct. 26.	Jan. 18.	New Ross	0·53	Nov. 2.	Jan. 24.
Buncrana	1·37	Nov. 5.	Jan. 28.	Passage West....	0·30	Oct. 21.	Jan. 14.
Port Rush	1·11	Nov. 14.	Feb. 3.	Castle Townsend..	0·08	Oct. 13.	Jan. 7.
Carrowkeel.....	1·31	Nov. 26.	Feb. 18.				

Section X.—*Method of expressing the height of the water, throughout every individual tide, by sines and cosines of arcs, and expressions in this form for every tide in the whole series of observations, except those at Courtown.*

The times of high water (and similarly those of low water) having had their principal irregularities smoothed down by the operations described in Section II., and being corrected for the diurnal equation in time ascertained by the operations of Section III., present a series of times, which are liable perhaps to something like constant error from the method involuntarily adopted by the computer in fixing on the time of high water, and which are affected by the peculiar form of the tidal function at each station, but which nevertheless follow at intervals equal (with very considerable accuracy) to the true tidal day of the place. This being understood, it will be seen that the following process entirely corrects any error of the supposed times of high or low water in its exhibition of the time of maximum of the first tidal argument, and is entirely free from the effects of such error in the exhibition of other quantities.

The whole number of observations, equidistant in time, made in the course of one tide, being about 150, if we divide this duration into sixteen equal parts we shall have at least nine observations in each part; and the mean time of these nine observations cannot in any case be more than $2\frac{1}{2}$ minutes from the middle of that part. It appears evident here that we may use the mean of all the heights in one portion to represent (with smaller error than unavoidably occurs in the observations) the

mean which would have been obtained if observations had been taken at infinitely small equal intervals. The same remark applies in a stronger degree if the whole duration be divided into twelve parts.

Let us use the term *phase* for an angle proportional to the time which increases by 360° in a complete tide; and let it be assumed that the height of the water can be expressed by the following formula:

$$A_0 + A_1 \sin \text{phase} + A_2 \sin 2 \text{ phase} + A_3 \sin 3 \text{ phase} + A_4 \sin 4 \text{ phase}$$
$$+ B_1 \cos \text{phase} + B_2 \cos 2 \text{ phase} + B_3 \cos 3 \text{ phase} + B_4 \cos 4 \text{ phase},$$

and suppose that the complete tide, or 360° of phase, is divided into sixteen equal parts and the mean height in each part taken.

The mean height in the first part will be,

$$A_0 + \frac{8}{\pi}A_1\left(\cos 0 - \cos\frac{\pi}{8}\right) + \frac{8}{2\pi}A_2\left(\cos 0 - \cos\frac{2\pi}{8}\right) + \frac{8}{3\pi}A_3\left(\cos 0 - \cos\frac{3\pi}{8}\right) + \frac{8}{4\pi}A_4\left(\cos 0 - \cos\frac{4\pi}{8}\right)$$
$$+ \frac{8}{\pi}B_1\left(\sin\frac{\pi}{8} - \sin 0\right) + \frac{8}{2\pi}B_2\left(\sin\frac{2\pi}{8} - \sin 0\right) + \frac{8}{3\pi}B_3\left(\sin\frac{3\pi}{8} - \sin 0\right) + \frac{8}{4\pi}B_4\left(\sin\frac{4\pi}{8} - \sin 0\right).$$

The mean height in the second part will be,

$$A_0 + \frac{8}{\pi}A_1\left(\cos\frac{\pi}{8} - \cos\frac{2\pi}{8}\right) + \frac{8}{2\pi}A_2\left(\cos\frac{2\pi}{8} - \cos\frac{4\pi}{8}\right) + \frac{8}{3\pi}A_3\left(\cos\frac{3\pi}{8} - \cos\frac{6\pi}{8}\right) + \frac{8}{4\pi}A_4\left(\cos\frac{4\pi}{8} - \cos\frac{8\pi}{8}\right)$$
$$+ \frac{8}{\pi}B_1\left(\sin\frac{2\pi}{8} - \sin\frac{\pi}{8}\right) + \frac{8}{2\pi}B_2\left(\sin\frac{4\pi}{8} - \sin\frac{2\pi}{8}\right) + \frac{8}{3\pi}B_3\left(\sin\frac{6\pi}{8} - \sin\frac{3\pi}{8}\right) + \frac{8}{4\pi}B_4\left(\sin\frac{8\pi}{8} - \sin\frac{4\pi}{8}\right),$$

and so on.

Now if we group these in the following manner,

(1st+5th+9th+13th)+(2nd+6th+10th+14th)−(3rd+7th+11th+15th)
−(4th+8th+12th+16th),

the sum will be $\frac{32}{\pi}A_4$.

If we group them in the following manner,

(1st+5th+9th+13th)−(2nd+6th+10th+14th)−(3rd+7th+11th+15th)
+(4th+8th+12th+16th),

the sum will be $\frac{32}{\pi}B_4$.

If we unite the adjacent means and group them thus,

(1st+2nd+9th+10th)+(3rd+4th+11th+12th)−(5th+6th+13th+14th)
−(7th+8th+15th+16th),

the sum will be $\frac{32}{\pi}A_2$.

If we group them in this manner,

(1st+2nd+9th+10th)−(3rd+4th+11th+12th)−(5th+6th+13th+14th)
+(7th+8th+15th+16th),

the sum will be $\frac{32}{\pi}B_2$.

If we unite the adjacent numbers already formed by union, so as to have the sum of four adjacent means together, and combine them thus,

$$(1st+2nd+3rd+4th)+(5th+6th+7th+8th)-(9th+10th+11th+12th)$$
$$-(13th+14th+15th+16th),$$

the sum is $\frac{32}{\pi}A_1+\frac{32}{3\pi}A_3$.

If we combine them in this manner,

$$(1st+2nd+3rd+4th)-(5th+6th+7th+8th)-(9th+10th+11th+12th)$$
$$+(13th+14th+15th+16th),$$

the sum is $\frac{32}{\pi}B_1-\frac{32}{3\pi}B_3$.

Then if we divide the complete tide into twelve equal parts, and take the mean height in each, we shall have

Mean height in the first part =

$$A_0+\frac{6}{\pi}A_1\left(\cos 0-\cos\frac{\pi}{6}\right)+\frac{6}{2\pi}A_2\left(\cos 0-\cos\frac{2\pi}{6}\right)+\frac{6}{3\pi}A_3\left(\cos 0-\cos\frac{3\pi}{6}\right)+\frac{6}{4\pi}A_4\left(\cos 0-\cos\frac{4\pi}{6}\right)$$
$$+\frac{6}{\pi}B_1\left(\sin\frac{\pi}{6}-\sin 0\right)+\frac{6}{2\pi}B_2\left(\sin\frac{2\pi}{6}-\sin 0\right)+\frac{6}{3\pi}B_3\left(\sin\frac{3\pi}{6}-\sin 0\right)+\frac{6}{4\pi}B_4\left(\sin\frac{4\pi}{6}-\sin 0\right),$$

and so on. And combining these in the following manner,

$$(1st+5th+9th)+(2nd+6th+10th)-(3rd+7th+11th)-(4th+8th+12th),$$

the sum will be $\frac{24}{\pi}A_3$, or the sum $\times\frac{4}{3}=\frac{32}{\pi}A_3$.

And if we combine them in the following manner,

$$(1st+5th+9th)-(2nd+6th+10th)-(3rd+7th+11th)+(4th+8th+12th),$$

the sum will be $\frac{24}{\pi}B_3$, or the sum $\times\frac{4}{3}=\frac{32}{\pi}B_3$.

By applying one-third of these to the expressions last found, we shall obtain $\frac{32}{\pi}A_1$ and $\frac{32}{\pi}B_1$.

The mean of all the means, either in the division by sixteen or in that by twelve, is A_0.

The whole of these operations (after taking the means of the original observations) are performed with great facility, and without the possibility of mistake, by means of a printed skeleton form, of which a specimen will be given shortly.

The next thing to be considered is, how we shall correct these numbers for the effect of diurnal tide, which is included in the observations, but from which our formula for semidiurnal tide is to be freed. Suppose that the tide begins with high water, and suppose a to be the effect of diurnal tide at that high water, b the effect of diurnal tide at the low water following, or that which occurs in the middle of the tide. Then the complete effect of diurnal tide is represented by

$$a\,.\cos\frac{\text{phase}}{2}+b\,.\sin\frac{\text{phase}}{2};$$

and the question now is, how this function can be represented, through the course of one tide, by a formula similar to

$$A_0 + A_1 \sin \text{phase} + A_2 \sin 2 \text{ phase} + \&c.$$
$$+ B_1 \cos \text{phase} + B_2 \cos 2 \text{ phase} + \&c.$$

For this purpose I have taken the mean value of the function for each sixteenth part, and for each twelfth part, of the entire circle of phase, and have combined these numbers according to the rules just laid down. The result is that

The sum $\frac{32}{\pi} A_4$ is increased by $\frac{16}{\pi} \times 0{\cdot}3980 \times a$.

The sum $\frac{32}{\pi} B_4$ is increased by $-\frac{16}{\pi} \times 0{\cdot}0392 \times b$.

The sum $\frac{32}{\pi} A_2$ is increased by $\frac{16}{\pi} \times 0{\cdot}8284 \times a$.

The sum $\frac{32}{\pi} B_2$ is increased by $-\frac{16}{\pi} \times 0{\cdot}1648 \times b$.

The sum $\frac{32}{\pi} A_1 + \frac{32}{3\pi} A_3$ is increased by $\frac{16}{\pi} \times 2a$.

The sum $\frac{32}{\pi} B_1 - \frac{32}{3\pi} B_3$ is increased by $-\frac{16}{\pi} \times 0{\cdot}8284 \times b$.

The sum $\frac{24}{\pi} A_3$ is increased by $\frac{12}{\pi} \times 0{\cdot}5360 \times a$.

The sum $\frac{24}{\pi} B_3$ is increased by $-\frac{12}{\pi} \times 0{\cdot}0704 \times b$.

The mean, or A_0, is increased by $+\frac{2}{\pi} b$.

The corrections are to be applied with opposite signs, in order to free from the effects of diurnal tide the results given by the observations.

Another cause for which a correction is due is, the difference of height at the beginning and at the end (the correction for diurnal tide being previously applied). If the whole rise c be supposed to have come by uniform degrees, the effects produced in the sums $\frac{32}{\pi} A_4$, $\frac{32}{\pi} A_2$, $\frac{32}{\pi} A_1 + \frac{32}{3\pi} A_3$, and $\frac{24}{\pi} A_3$, are $-c$, $-2c$, $-4c$, and $-c$. The corrections must have opposite signs.

In this manner (confining ourselves for a moment to the consideration of 4 phase) we have such expressions as $\frac{32}{\pi} A_4$ and $\frac{32}{\pi} B_4$. And the quantity which we wish to obtain is $A_4 \sin 4 \text{ phase} + B_4 \cos 4 \text{ phase}$, which may be converted into one of this form, $\sqrt{A_4^2 + B_4^2} \times \sin . 4 \text{ phase} + \varphi$, where $\tan \varphi = \frac{B_4}{A_4}$. The coefficient is

$$= \frac{\pi}{32} \sqrt{\left(\frac{32}{\pi} A_4\right)^2 + \left(\frac{32}{\pi} B_4\right)^2}.$$

As in the analysis of all the tides, this transformation was to be performed about 6000 times, it was highly important to devise an easy method of effecting it. For this purpose the following mechanical arrangement was contrived. Upon a nearly square piece of pasteboard were carefully traced two scales at right angles to each other, with graduations of equal parts proceeding from the point of union. Upon the edge of another narrow piece of pasteboard was traced a graduation whose parts were to the parts of the former in the proportion of 3·2 to 3·1416. The commencing point of this graduation was made the centre of a quadrant, of which one radius was in the line of graduation produced. The divisions of the quadrant, proceeding from the line of graduation, were marked from 0 to 90°, and also from 360° to 270°. The method of using it was; to insert a needle at the centre of the quadrant, and to plant its point upon one of the lines of the large pasteboard at the graduation corresponding to $\frac{32}{\pi}A_4$; then to plant a second needle in the other line of the large pasteboard at the graduation corresponding to $\frac{32}{\pi}B_4$, and to turn the graduated edge of the long piece till it touched this second needle; the reading of the graduated edge, with a shift of the decimal point, gave $\frac{\pi}{32}\sqrt{\left\{\left(\frac{32}{\pi}A_4\right)^2+\left(\frac{32}{\pi}B_4\right)^2\right\}}$ or $\sqrt{(A_4^2+B_4^2)}$; and the division of the quadrant cut by the straight line on the large pasteboard gave φ. When the signs of $\frac{32}{\pi}A_4$ and $\frac{32}{\pi}B_4$ are the same, the reading between 0 and 90° is to be taken; when different, that between 360° and 270° is to be taken; and in either case, when $\frac{32}{\pi}A_4$ is negative, 180° is to be added or subtracted.

Applying the same process to the four combinations of A_1 and B_1, A_2 and B_2, A_3 and B_3, A_4 and B_4, we have the height of the water at every instant expressed by the formula

$$A_0+C_1\sin(\text{phase}+\varphi_1)+C_2\sin(2\ \text{phase}+\varphi_2)+C_3\sin(3\ \text{phase}+\varphi_3)+C_4\sin(4\ \text{phase}+\varphi_4),$$

where the *phase* is an angle which is measured from the assumed commencement of the tide, and may be converted into time by multiplying it by $\frac{\text{whole duration of tide}}{360°}$. It is evident however that the argument (phase $+\varphi_1$) commences at the time when the water would be at its mean height before attaining its greatest height, if the oscillation of surface were supposed to depend on that term only. The time of high water, on the same supposition, would be given by making phase $+\varphi_1=90°$, or phase $=90°-\varphi_1$; converting the expression, when found, into time by the rule above. Or the time of low water, on the same supposition, would be given by making phase $+\varphi_1=270°$, or phase $=270°-\varphi_1$. It is convenient to choose, of these two expressions, that which gives the smaller quantity. The quantity so found is to be added to the Greenwich time of assumed commencement of tide, and it gives the Greenwich time of high

water or low water, on the supposition that the fluctuation depends entirely on the argument (phase $+\varphi_1$). Since the Theory of Waves, as applied to Tides, leads us to refer every angle to that argument, and induces us to suppose that the term connected with that argument is the only one which is immediately created by the tidal forces (the others depending numerically on it almost in the same way in which the coefficients of successive multiples of *anomaly* depend on that of the simple *anomaly*), it appears to be proper to consider the times of high and low water thus found as the genuine times of high and low water. For the sake of distinction I call them the Analysed Times.

As it is convenient to use the time of one phase only, I have, when the analysis gave the Analysed Times of two low waters, taken their mean for the Analysed Time of High Water.

Now if we put phase $+\varphi_1=p$, $\varphi_2-2\varphi_1=c_2$, $\varphi_3-3\varphi_1=c_3$, $\varphi_4-4\varphi_1=c_4$, our expression for the height at every instant will be

$$A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4),$$

and this, with a statement of the time at which the argument p has the value of 90° (or the Analysed Time of High Water), gives a complete knowledge of the form of every tide.

I annex a specimen of the printed skeleton form in which the calculations described in this section were made (the figures, and the words in italics, being inserted for each special tide). And I subjoin the whole of the results for the twenty-one stations. Each line is the digested result of about 170 observations.

Station—*Limerick*. Limits of Tide, *June* 25^d 20^h 38^m to *June* 26^d 8^h 52^m. Commencing with corrected *High* Water. Coefficients for Diurnal Tide, $a = -0^f{\cdot}30$, $b = +1^f{\cdot}13$.
Rise of Tide from beginning to end (after correction for Diurnal Tide) $= 0^f{\cdot}88$.

Means of Heights in Sixteenth Portions of Tide. For 4 Phase.					Sums of adjacent Means. For 2 Phase.				Sums of adjacent Sums. For Phase.				Means of Heights in Twelfth Portions of Tides. For 3 Phase.				
1st portion	18·33				35·61				63·54				1st	18·20			
2nd portion		17·28				27·93				26·68			2nd		16·17		
3rd portion			15·10				18·12				29·67		3rd			13·19	
4th portion				12·83				8·56				64·97	4th				9·95
5th portion	10·39												5th	6·33			
6th portion		7·73											6th		3·72		
7th portion			5·07										7th			3·09	
8th portion				3·49									8th				7·56
9th portion	2·71				8·38								9th	11·60			
10th portion		5·67				21·29							10th		14·16		
11th portion			9·27				29·50						11th			16·64	
12th portion				12·02				35·47					12th				18·02
13th portion	13·82																
14th portion		15·68															
15th portion			17·36														
16th portion				18·11													
Sums	45·25 I.	46·36 II.	46·80 III.	46·45 IV.	43·99 I.	49·22 II.	47·62 III.	44·03 IV.	63·54 I.	26·68 II.	29·67 III.	64·97 IV.		36·13 I.	34·05 II.	32·92 III.	35·53 IV.
I. + II.				91·61				93·21				90·22					70·18
Subtract III. + IV.				93·25				91·65				94·64					68·45
				− 1·64				+ 1·56				− 4·42					+ 1·73
Add for a				+ 0·61				+ 1·27				+ 2·79					+ 0·61
				− 1·03				+ 2·83				− 1·63					+ 2·34
Add for Rise				− 0·88				− 1·76				− 3·23					− 0·88
												− 4·86					+ 1·46
									Add − ½ No. for sine 3 phase			− 0·65				Add one-third	+ 0·49
	Number for sine 4 phase			− 1·91	Number for sine 2 phase			+ 1·07	Number for sine phase			− 5·51		Number for sine 3 phase			+ 1·95
I. + IV.				91·70				88·02				128·51					71·66
Subtract II. + III.				93·16				96·84				56·35					66·97
				− 1·46				− 8·82				+72·16					+ 4·69
Add for b				+ 0·23				+ 0·95				+ 4·90					+ 0·31
												+77·06					+ 5·00
									Add ½ No. for cosine 3 phase			+ 2·22				Add one-third	+ 1·67
	Number for cosine 4 phase			− 1·23	Number for cosine 2 phase			− 7·87	Number for cosine phase			+79·28		Number for cosine 3 phase			+ 6·67
I. + II. + III. + IV. = 184·86					One-fourth = 46·21				One-sixteenth = 11·55				I. + II. + III. + IV. = 138·63 one-twelfth = 11·55				
					Add for b							− 0·72				Add for b	− 0·72

Therefore the expression for the height in semidiurnal tide is

ft.
$$\left\{\begin{array}{l} 10{\cdot}83 \\ +7{\cdot}82 \times \text{sine}\,(\text{phase} + 93^\circ\ 45') \\ +0{\cdot}78 \times \text{sine}\,(2\,\text{phase} + 277^\circ\ 35') \\ +0{\cdot}68 \times \text{sine}\,(3\,\text{phase} + 73^\circ\ 45') \\ +0{\cdot}22 \times \text{sine}\,(4\,\text{phase} + 213^\circ\ 35') \end{array}\right\} \text{ or } \left\{\begin{array}{l} 10{\cdot}83 \\ +7{\cdot}82 \times \text{sine}\,p \\ +0{\cdot}78 \times \text{sine}\,(2p + 90^\circ\ 5') \\ +0{\cdot}68 \times \text{sine}\,(3p + 152^\circ\ 30') \\ +0{\cdot}22 \times \text{sine}\,(4p + 198^\circ\ 35'). \end{array}\right\}$$

And the correction to the assumed times of *High* Water is $\frac{-3^\circ\ 45' \times 735^m}{360^\circ} = -8^m$.

(Note. The first term is yet to be increased by 7$^f{\cdot}58$, for the difference of level between the zero of the tide-gauge and the point 30 feet below the bolt at Buckingham Lock.)

Height of the Water in each individual tide at Kilbaha, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
June 24. 18 29	16·40	5·10	0·14	146	0·19	215	0·06	115
25. 6 39								
25. 18 59	15·79	5·05	0·13	199	0·09	318	0·01	40
26. 7 13								
26. 19 27	15·50	4·71	0·18	170	0·03	291	0·05	140
27. 7 46								
27. 20 0	15·65	4·20	0·08	158	0·07	204	0·09	82
28. 8 20								
28. 20 43	15·52	3·76	0·13	199	0·05	192	0·02	99
29. 9 0								
29. 21 32	15·65	3·25	0·10	210	0·08	244	0·02	55
30. 10 2								
30. 22 25	15·70	2·93	0·04	144	0·06	227	0·03	151
July 1. 10 57								
1. 23 29	15·51	2·73	0·06	216	0·08	231	0·02	52
2. 12 2								
3. 0 35	15·96	2·82	0·02	232	0·07	225	0·06	109
3. 13 11								
4. 1 46	16·41	3·36	0·12	212	0·07	281	0·04	55
4. 14 13								
5. 2 39	15·49	3·95	0·12	216	0·09	262	0·03	37
5. 15 6								
6. 3 32	15·43	4·73	0·10	187	0·09	288	0·04	230
6. 15 54								
7. 4 21	16·00	5·32	0·04	153	0·01	210	0·01	289
7. 16 42								
8. 5 0	16·05	5·86	0·03	225	0·09	255	0·04	88
8. 17 22								
9. 5 42	15·96	6·33	0·14	132	0·04	217	0·02	44
9. 18 16								
10. 6 40	15·98	6·80	0·17	142	0·14	248	0·08	61
10. 18 46								
11. 7 10	16·12	6·80	0·26	155	0·14	305	0·07	154
11. 19 39								
12. 8 2	15·79	6·48	0·20	175	0·02	121	0·07	140
12. 20 31								
13. 8 55	15·46	5·88	0·29	211	0·10	226	0·03	67
13. 21 21								
14. 9 48	15·26	4·97	0·17	200	0·09	220	0·02	122
14. 22 24	15·39	4·36	0·08	205	0·11	256	0·01	176
15. 10 58								
15. 23 32	16·01	3·72	0·19	196	0·06	328	0·08	228
16. 12 10								
17. 0 48	16·00	3·47	0·09	237	0·04	247	0·04	4
17. 13 27								
18. 2 5	15·80	3·70	0·15	238	0·11	265	0·04	207
18. 14 36								
19. 3 6	15·72	4·15	0·09	276	0·05	288	0·03	148
19. 15 32								
20. 3 59	15·76	4·48	0·03	152	0·07	215	0·05	210
20. 16 20								
21. 4 38	15·54	4·93	0·11	161	0·00	219	0·04	137
21. 16 53								
22. 5 9	15·56	5·35	0·08	182	0·02	350	0·04	174
22. 17 28								
23. 5 45	15·51	5·50	0·13	166	0·01	112	0·03	28

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 2	15·47	5·55	0·14	152	0·05	226	0·02	28
24. 6 18								
24. 18 32	15·58	5·47	0·20	140	0·03	128	0·03	56
25. 6 52								
25. 19 5	15·48	5·19	0·18	154	0·01	214	0·03	27
26. 7 22								
26. 19 39	15·31	4·81	0·16	175	0·02	209	0·05	77
27. 7 55								
27. 20 12	15·28	4·28	0·12	187	0·07	196	0·04	236
28. 8 27								
28. 20 52	15·17	3·69	0·15	189	0·06	226	0·02	47
29. 9 11								
29. 21 32	15·32	3·30	0·15	149	0·09	267	0·02	66
30. 9 59								
30. 22 26	15·25	2·73	0·04	204	0·05	232	0·03	158
31. 11 6								
31. 23 46	15·45	2·57	0·06	182	0·05	199	0·02	338
August 1. 12 27								
2. 1 8	15·75	2·90	0·03	218	0·03	76	0·02	132
2. 13 43								
3. 2 18	15·38	3·62	0·01	261	0·05	240	0·06	60
3. 14 45								
4. 3 11	15·45	4·55	0·07	205	0·09	215	0·11	104
4. 15 34								
5. 3 54	15·68	5·30	0·03	192	0·10	218	0·04	197
5. 16 18								
6. 4 42	15·70	6·32	0·05	135	0·08	233	0·05	0
6. 17 2								
7. 5 22	15·80	7·30	0·21	170	0·04	7	0·04	184
7. 17 39								
8. 6 2	15·89	7·63	0·18	148	0·05	127	0·07	100
8. 18 27								
9. 6 48	15·94	7·62	0·32	168	0·03	266	0·05	91
9. 19 10								
10. 7 34	15·76	7·08	0·24	161	0·10	221	0·07	74
10. 19 55								
11. 8 21	15·63	6·12	0·29	168	0·06	193	0·05	71
11. 20 45								
12. 9 8	15·64	5·01	0·19	178	0·07	206	0·06	72
12. 21 45	15·41	4·06	0·13	227	0·13	242	0·04	159
13. 10 22								
13. 22 58	15·27	3·24	0·10	244	0·11	309	0·02	180
14. 11 43								
15. 0 27	15·27	2·79	0·12	221	0·07	269	0·01	0
15. 13 9								
16. 1 50	15·41	3·16	0·06	235	0·10	268	0·02	316
16. 14 19								
17. 2 48	15·59	3·71	0·05	238	0·05	279	0·00	51
17. 15 10								
18. 3 31	15·64	4·32	0·09	203	0·05	270	0·01	24
18. 15 50								
19. 4 11	15·76	4·76	0·08	121	0·05	178	0·02	108
19. 16 29								
20. 4 43	15·74	5·29	0·13	165	0·09	242	0·03	189
20. 16 55								
21. 5 11	15·54	5·73	0·11	177	0·06	232	0·04	163
21. 17 26								
22. 5 38	15·24	5·86	0·16	149	0·05	154	0·04	127
22. 17 54								
23. 6 12	15·58	5·80	0·15	135	0·10	222	0·04	88

Height of the Water in each individual tide at Kilrush, excluding diurnal tide,

Analysed time of high water, corresponding to $p = 90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 23. 17 50	17·14	5·90	0·17	111	0·07	284	0·07	167
24. 6 11								
24. 18 42	17·20	5·53	0·21	105	0·08	155	0·06	141
25. 6 52								
25. 19 14	16·62	5·47	0·12	119	0·05	261	0·11	175
26. 7 28								
26. 19 32	16·29	5·18	0·20	124	0·07	231	0·10	146
27. 7 51								
27. 20 23	16·40	4·63	0·16	150	0·05	153	0·04	107
28. 8 43								
28. 20 52	16·48	4·23	0·42	116	0·17	139	0·03	97
29. 9 17								
29. 21 41	16·36	3·80	0·16	106	0·05	194	0·05	130
30. 10 7								
30. 22 33	16·52	3·39	0·11	86	0·01	30	0·03	230
July 1. 11 4								
1. 23 35	16·30	3·12	0·10	135	0·09	186	0·00	130
2. 12 13								
3. 0 50	16·74	3·22	0·10	84	0·06	208	0·01	240
3. 13 21								
4. 1 52	17·25	3·75	0·16	150	0·07	201	0·02	269
4. 14 19								
5. 2 45	16·51	4·50	0·12	136	0·09	237	0·01	333
5. 14 58	16·20	5·13	0·15	314	0·17	177	0·08	23
6. 3 26								
6. 15 57	16·75	5·71	0·17	58	0·06	257	0·02	181
7. 4 24								
7. 16 52	16·90	6·30	0·11	80	0·11	258	0·06	134
8. 5 10								
8. 17 25	16·63	6·87	0·20	77	0·12	155	0·05	205
9. 5 45								
9. 18 9	16·86	7·17	0·31	99	0·09	254	0·13	184
10. 6 33								
10. 18 58	17·02	7·15	0·23	103	0·02	239	0·05	210
11. 7 22								
11. 19 40	16·70	6·82	0·17	100	0·04	76	0·05	119
12. 8 3								
12. 20 32	16·35	6·13	0·24	152	0·09	161	0·01	44
13. 8 56								
13. 21 21	16·00	5·43	0·18	125	0·06	194	0·03	179
14. 9 48								
14. 22 25	16·10	4·78	0·10	159	0·13	264	0·05	170
15. 10 58								
15. 23 30	16·63	4·18	0·18	151	0·07	267	0·02	318
16. 12 11								
17. 0 51	16·70	3·99	0·07	190	0·03	201	0·02	218
17. 13 28								
18. 2 4	16·60	4·11	0·11	140	0·09	241	0·04	201
18. 14 36								
19. 3 8	16·45	4·64	0·05	128	0·03	254	0·07	167
19. 15 30	16·46	5·01	0·10	60	0·08	173	0·05	136
20. 3 57								
20. 16 24	16·24	5·43	0·13	101	0·04	112	0·03	167
21. 4 42								
21. 17 3	16·29	5·82	0·12	100	0·04	194	0·03	144
22. 5 19								
22. 17 39	16·28	6·02	0·20	111	0·04	179	0·03	193
23. 5 56								

The value $c_2 = 314°$ for July 5 and 6 is correct.

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 12	16·31	6·02	0·21	120	0·09	228	0·05	205
24. 6 28								
24. 18 40	16·36	5·87	0·26	100	0·06	184	0·03	123
25. 7 0								
25. 19 15	16·21	5·69	0·26	122	0·04	206	0·07	146
26. 7 32								
26. 19 50	15·98	5·29	0·15	153	0·02	211	0·01	95
27. 8 6								
27. 20 18	15·95	4·82	0·19	129	0·07	165	0·08	146
28. 8 33								
28. 20 56	15·80	4·20	0·20	143	0·06	204	0·02	259
29. 9 15								
29. 21 33	16·02	3·72	0·23	118	0·10	215	0·02	119
30. 10 6								
30. 22 38	15·98	3·10	0·09	142	0·04	224	0·01	253
31. 11 15								
31. 23 51	16·14	2·89	0·12	117	0·09	210	0·01	29
August 1. 12 31								
2. 1 10	16·59	3·33	0·11	143	0·06	226	0·04	206
2. 13 52								
3. 2 33	16·32	4·15	0·16	124	0·08	223	0·02	213
3. 15 7								
4. 3 35	16·34	4·89	0·13	117	0·06	234	0·03	266
4. 15 57								
5. 4 17	16·64	5·86	0·11	115	0·03	285	0·10	185
5. 16 42								
6. 5 6	16·68	6·87	0·22	82	0·07	195	0·06	151
6. 17 30								
7. 5 50	16·80	7·59	0·25	71	0·11	219	0·06	128
7. 18 9								
8. 6 32	16·76	7·96	0·34	91	0·10	208	0·08	199
8. 18 57								
9. 7 18	16·69	7·95	0·25	116	0·11	217	0·03	231
9. 19 38								
10. 8 2	16·51	7·49	0·24	113	0·10	198	0·02	123
10. 20 23								
11. 8 49	16·36	6·62	0·29	127	0·16	197	0·07	78
11. 21 12								
12. 9 35	16·38	5·50	0·15	138	0·11	183	0·06	116
12. 22 7	16·17	4·58	0·11	150	0·11	213	0·07	175
13. 10 41								
13. 23 14	15·98	3·76	0·13	148	0·08	240	0·07	212
14. 11 59								
15. 0 43	16·07	3·29	0·12	153	0·06	235	0·02	284
15. 13 25								
16. 2 7	16·24	3·69	0·10	148	0·05	265	0·03	190
16. 14 37								
17. 3 7	16·53	4·30	0·11	117	0·03	123	0·01	231
17. 15 28								
18. 3 50	16·39	4·70	0·15	31	0·15	208	0·08	117
18. 16 10								
19. 4 31	16·55	5·33	0·14	84	0·11	170	0·01	209
19. 16 54								
20. 5 8	16·53	5·80	0·24	112	0·06	216	0·07	164
20. 17 16								
21. 5 32	16·31	6·20	0·13	60	0·08	211	0·03	65
21. 17 50								
22. 6 2	16·00	6·32	0·21	109	0·12	150	0·04	130
22. 18 13								
23. 6 31	16·42	6·36	0·18	68	0·14	176	0·08	72

Height of the Water in each individual tide at Foynes Island, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
June 25. 19 55	17·57	6·38	0·36	122	0·15	160	0·08	289
26. 8 9								
26. 20 26	17·05	6·01	0·49	116	0·15	166	0·06	232
27. 8 45								
27. 21 0	17·21	5·52	0·42	128	0·11	168	0·04	107
28. 9 20								
28. 21 34	17·08	5·22	0·39	116	0·12	143	0·02	274
29. 9 52								
29. 22 12	17·03	4·57	0·38	107	0·08	160	0·04	71
30. 10 37								
30. 23 3	17·25	4·16	0·28	113	0·06	163	0·04	152
July 1. 11 34								
2. 0 4	17·14	3·91	0·34	122	0·09	146	0·03	268
2. 12 40								
3. 1 16	17·43	3·88	0·39	127	0·16	192	0·04	351
3. 13 55								
4. 2 33	18·04	4·38	0·34	126	0·13	182	0·04	331
4. 14 56								
5. 3 20	17·37	5·00	0·21	111	0·19	189	0·03	280
5. 15 52								
6. 4 24	16·88	5·81	0·43	115	0·13	185	0·02	167
6. 16 54								
7. 5 21	17·48	6·50	0·41	109	0·19	163	0·03	329
7. 17 48								
8. 6 6	17·67	7·13	0·34	113	0·22	165	0·11	25
8. 18 30								
9. 6 50	17·40	7·68	0·54	115	0·37	165	0·07	279
9. 19 20								
10. 7 44	17·38	8·03	0·50	128	0·28	199	0·15	271
10. 20 2								
11. 8 26	17·70	7·94	0·60	102	0·37	179	0·02	20
11. 20 48								
12. 9 11	17·43	7·66	0·57	116	0·24	167	0·03	4
12. 21 38	17·40	7·22	0·51	114	0·30	159	0·06	287
13. 9 59								
13. 22 20	16·77	6·57	0·55	119	0·19	175	0·09	282
14. 10 47								
14. 23 14	16·71	5·65	0·41	128	0·14	189	0·02	30
15. 11 46								
16. 0 18	17·16	4·97	0·36	131	0·12	175	0·07	33
16. 12 57								
17. 1 35	17·35	4·72	0·32	144	0·13	162	0·03	348
17. 14 11								
18. 2 47	17·29	4·91	0·35	137	0·15	186	0·04	310
18. 15 21								
19. 3 50	17·18	5·25	0·32	125	0·10	183	0·01	290
19. 16 15								
20. 4 42	17·18	5·77	0·44	120	0·14	155	0·03	280
20. 17 8								
21. 5 26	17·00	6·28	0·47	120	0·14	168	0·03	264
21. 17 48								
22. 6 4	17·02	6·65	0·47	116	0·18	179	0·02	284
22. 18 22								
23. 6 39	17·08	6·82	0·59	109	0·29	165	0·05	220

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 55	16·99	6·89	0·61	113	0·21	172	0·02	10
24. 7 11								
24. 19 23	17·06	6·80	0·60	115	0·18	159	0·04	306
25. 7 43								
25. 19 55	16·93	6·50	0·61	116	0·22	160	0·02	307
26. 8 12								
26. 20 25	16·77	6·11	0·58	123	0·16	159	0·00	202
27. 8 41								
27. 20 54	16·78	5·80	0·55	110	0·15	152	0·05	92
28. 9 11								
28. 21 27	16·60	5·19	0·47	110	0·10	139	0·06	135
29. 9 47								
29. 22 6	16·78	4·52	0·46	113	0·09	186	0·01	210
30. 10 33								
30. 23 0	16·68	3·86	0·35	119	0·06	173	0·04	61
31. 11 39								
August 1. 0 17	16·89	3·64	0·39	127	0·13	190	0·03	335
1. 13 1								
2. 1 45	17·20	4·07	0·38	137	0·12	198	0·05	304
2. 14 24								
3. 3 2	17 00	4·89	0·44	131	0·12	189	0·03	269
3. 15 37								
4. 4 7	17·16	5·66	0·34	115	0·13	171	0·00	122
4. 16 37								
5. 4 57	17·38	6·59	0·43	121	0·22	165	0·02	287
5. 17 27								
6. 5 51	17·38	7·71	0·55	107	0·29	160	0·01	35
6. 18 17								
7. 6 37	17·53	8·29	0·64	102	0·37	162	0·04	259
7. 18 57								
8. 7 20	17·57	8·58	0·74	112	0·45	165	0·11	249
8. 19 45								
9. 8 6	17·56	8·51	0·72	114	0·39	171	0·09	283
9. 20 25								
10. 8 49	17·48	8·12	0·71	114	0·34	167	0·09	261
10. 21 7	17·13	7·56	0·64	111	0·28	167	0·01	77
11. 9 28								
11. 21 48	17·22	6·66	0·59	118	0·25	159	0·04	292
12. 10 14								
12. 22 39	16·93	5·40	0·40	122	0·13	166	0·03	77
13. 11 9								
13. 23 39	16·72	4·40	0·33	140	0·05	183	0·00	133
14. 12 23								
15. 1 7	16·72	3·91	0·36	140	0·12	209	0·02	337
15. 13 50								
16. 2 33	16·77	4·30	0·32	145	0·09	204	0·03	356
16. 15 9								
17. 3 39	17·06	4·80	0·33	124	0·08	177	0·01	175
17. 16 5								
18. 4 30	17·11	5·47	0·41	115	0·11	173	0·02	259
18. 16 51								
19. 5 12	17·28	6·15	0·50	113	0·19	163	0·02	109
19. 17 35								
20. 5 49	17·25	6·60	0·47	106	0·22	181	0·04	307
20. 18 3								
21. 6 19	17·04	6·99	0·60	109	0·23	167	0·04	54
21. 18 35								
22. 6 47	16·73	7·10	0·57	111	0·24	175	0·03	350
22. 19 0								
23. 7 18	17·10	7·66	0·59	111	0·30	167	0·02	22

Height of the Water in each individual tide at Limerick, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	ϵ_2.	C_3.	ϵ_3.	C_4.	ϵ_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
June 25. 20 30	18·41	7·82	0·78	90	0·68	153	0·22	199
26. 8 44								
26. 21 3	17·54	7·93	1·23	86	0·84	119	0·45	155
27. 9 17								
27. 21 30	17·72	7·07	1·02	96	0·64	129	0·24	174
28. 9 46								
28. 22 1	17·50	6·62	1·01	103	0·51	124	0·17	167
29. 10 19								
29. 22 37	17·24	5·92	0·87	97	0·48	129	0·20	167
30. 10 59								
30. 23 20	18·12	5·33	0·71	108	0·34	142	0·10	153
July 1. 11 50								
2. 0 20	17·98	5·03	0·76	118	0·27	151	0·08	225
2. 12 56								
3. 1 31	17·78	5·11	0·92	121	0·43	146	0·25	203
3. 14 16								
4. 3 0	18·45	5·67	0·97	125	0·38	172	0·18	221
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
5. 16 17								
6. 4 53	17·28	7·18	0·79	106	0·46	155	0·28	191
6. 17 23								
7. 5 50	18·11	7·97	0·72	97	0·69	143	0·40	204
7. 18 15								
8. 6 33	18·65	8·32	0·67	95	0·86	148	0·24	221
8. 19 0								
9. 7 20	18·36	9·21	0·87	90	0·83	136	0·35	173
9. 20 0	18·18	9·78	0·90	66	0·84	123	0·62	138
10. 8 23								
10. 20 45	18·40	9·83	1·02	64	0·84	119	0·63	133
11. 9 6								
11. 21 27	18·00	9·67	1·09	69	0·89	115	0·53	135
12. 9 54								
12. 22 20	18·57	8·69	1·03	80	0·93	130	0·47	160
13. 10 37								
13. 22 54	17·45	8·06	0·89	91	0·82	126	0·54	161
14. 11 19								
14. 23 44	16·91	7·22	0·87	108	0·66	139	0·29	166
15. 12 14								
16. 0 44	17·14	6·27	0·89	124	0·36	172	0·12	244
16. 13 21								
17. 1 58	17·55	5·94	0·73	128	0·30	156	0·11	206
17. 14 35								
18. 3 11	17·38	6·10	0·76	119	0·58	160	0·13	195
18. 15 50								
19. 4 20	17·38	6·59	0·70	120	0·43	153	0·15	213
19. 16 48								
20. 5 15	17·45	7·17	0·87	106	0·49	143	0·16	189
20. 17 36								
21. 5 56	17·46	7·75	0·88	94	0·64	141	0·29	167
21. 18 21								
22. 6 37	17·50	8·12	1·02	90	0·73	135	0·38	157
22. 18 58								
23. 7 15	17·58	8·35	1·03	87	0·75	130	0·46	168

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 19 31 }	17·55	8·40	0·99	85	0·76	138	0·48	163
24. 7 47 }								
24. 20 8	17·42	8·50	0·97	76	0·83	111	0·52	138
25. 8 23								
25. 20 37	17·34	8·32	0·94	75	0·70	111	0·46	144
26. 8 51								
26. 21 5	17·10	7·87	0·95	85	0·67	113	0·46	147
27. 9 18								
27. 21 30	17·19	7·31	1·03	88	0·74	122	0·29	160
28. 9 43								
28. 21 55	16·86	6·71	1·11	91	0·59	115	0·40	183
29. 10 14								
29. 22 33	17·21	5·72	0·97	96	0·51	135	0·17	165
30. 10 56								
30. 23 19	16·94	4·95	0·75	110	0·29	142	0·06	214
31. 11 57								
August 1. 0 35	17·11	4·60	0·76	119	0·24	145	0·15	224
1. 13 31								
2. 2 26	17·44	4·31	0·73	113	0·35	165	0·16	264
2. 14 48 }	17·12	5·88	0·75	132	0·39	160	0·08	186
3. 3 25 }								
3. 16 3 }	17·65	6·81	0·63	105	0·49	143	0·31	185
4. 4 38 }								
4. 17 10 }	18·09	8·10	0·81	86	0·72	148	0·35	171
5. 5 30 }								
5. 18 5 }	18·02	9·30	1·09	75	0·81	127	0·51	146
6. 6 29 }								
6. 18 50 }	18·41	9·62	1·17	67	0·94	115	0·55	144
7. 7 10 }								
7. 19 45	17·99	10·38	0·99	35	0·74	101	0·64	117
8. 8 8								
8. 20 30	18·05	10·36	0·93	40	0·77	100	0·66	118
9. 8 48								
9. 21 6	18·16	9·95	0·96	52	0·91	107	0·69	122
10. 9 27								
10. 21 47	17·73	9·17	0·91	64	0·90	118	0·63	129
11. 10 5								
11. 22 23	17·77	8·24	0·88	85	0·89	122	0·42	152
12. 10 43								
12. 23 3	17·18	6·89	0·87	107	0·62	139	0·22	146
13. 11 31								
13. 23 58	16·87	5·56	0·79	130	0·37	169	0·09	201
14. 12 43								
15. 1 28	16·86	4·95	0·67	134	0·28	160	0·09	210
15. 14 8								
16. 2 47	16·85	5·50	0·75	125	0·39	165	0·13	204
16. 15 29 }	17·20	6·08	0·65	109	0·37	161	0·10	141
17. 3 56 }								
17. 16 29 }	17·33	6·87	0·80	106	0·46	143	0·24	195
18. 4 56 }								
18. 17 20 }	17·73	7·64	0·94	96	0·62	135	0·30	195
19. 5 41 }								
19. 18 7 }	17·84	8·05	1·10	89	0·79	143	0·38	172
20. 6 21 }								
20. 18 36 }	17·58	8·49	1·03	80	0·74	133	0·49	150
21. 6 52 }								
21. 19 9 }	17·18	8·71	0·98	76	0·74	118	0·51	126
22. 7 21 }								
22. 19 35 }	17·63	8·52	1·12	78	0·82	131	0·43	150
23. 7 53 }								

Height of the Water in each individual tide at Casleh Bay, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_φ	C_1.	C_2.	e_2.	C_3.	e_3.	C_4.	e_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
June 23. 17 56	18·57	5·70	0·17	211	0·10	233	0·03	354
24. 5 53								
24. 18 31	18·75	5·42	0·12	148	0·17	182	0·04	85
25. 6 41								
25. 19 1	18·14	5·29	0·04	269	0·08	245	0·08	341
26. 7 15								
26. 19 37	17·85	4·88	0·21	180	0·05	118	0·04	87
27. 7 56								
27. 20 15	18·08	4·28	0·15	197	0·09	230	0·07	329
28. 8 35								
28. 20 58	17·80	3·82	0·11	227	0·05	195	0·05	334
29. 9 15								
29. 21 39	17·93	3·33	0·13	192	0·06	240	0·03	16
30. 10 9								
30. 22 32	18·10	3·04	0·04	166	0·07	224	0·04	317
July 1. 11 5								
1. 23 37	17·74	2·77	0·05	254	0·10	188	0·01	213
2. 12 16								
3. 0 55	18·26	2·90	0·03	293	0·06	229	0·03	5
3. 13 26								
4. 1 57	18·83	3·43	0·07	196	0·07	268	0·05	158
4. 14 22								
5. 2 47	17·88	4·06	0·07	208	0·08	252	0·06	341
5. 15 14								
6. 3 40	17·80	4·92	0·06	142	0·13	280	0·03	110
6. 16 3								
7. 4 30	18·35	5·49	0·03	179	0·02	173	0·07	352
7. 16 53								
8. 5 11	18·39	6·18	0·07	288	0·25	239	0·09	347
8. 17 31								
9. 5 51	18·22	6·76	0·08	134	0·15	209	0·06	349
9. 18 16								
10. 6 40	18·21	7·09	0·20	176	0·17	235	0·10	51
10. 18 59								
11. 7 23	18·37	7·06	0·17	165	0·13	246	0·02	267
11. 19 46								
12. 8 9	18·16	6·75	0·20	199	0·08	245	0·07	354
12. 20 40								
13. 9 4	17·94	6·06	0·29	165	0·15	216	0·01	332
13. 21 28								
14. 9 55	17·57	5·12	0·16	195	0·14	180	0·06	345
14. 22 35	17·58	4·49	0·15	235	0·15	240	0·11	58
15. 11 12								
15. 23 48	18·25	3·74	0·14	256	0·07	358	0·04	79
16. 12 24								
17. 1 0	18·27	3·57	0·17	270	0·14	239	0·08	128
17. 13 38								
18. 2 16	18·20	3·80	0·14	247	0·14	234	0·02	93
18. 14 47								
19. 3 18	18·08	4·34	0·07	288	0·04	261	0·01	294
19. 15 42								
20. 4 5	17·98	4·79	0·11	191	0·05	160	0·04	9
20. 16 29								
21. 4 47	17·88	5·12	0·01	275	0·10	247	0·02	258
21. 16 55								
22. 5 11	17·83	5·55	0·07	208	0·06	228	0·08	10
22. 17 29								
23. 5 46	17·87	5·70	0·15	150	0·13	206	0·08	343

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 2	17·93	5·70	0·21	154	0·08	230	0·03	289
24. 6 18								
24. 18 32	17·86	5·66	0·19	141	0·05	208	0·07	329
25. 6 52								
25. 19 7	17·71	5·37	0·21	163	0·06	258	0·04	12
26. 7 24								
26. 19 41	17·56	4·97	0·18	176	0·07	196	0·03	329
27. 7 57								
27. 20 13	17·57	4·44	0·16	193	0·08	191	0·06	296
28. 8 28								
28. 20 50	17·44	3·75	0·18	179	0·04	196	0·05	313
29. 9 9								
29. 21 28	17·62	3·35	0·08	157	0·07	233	0·04	318
30. 9 59								
30. 22 29	17·50	2·79	0·05	240	0·04	170	0·05	84
31. 11 8								
31. 23 47	17·71	2·64	0·06	190	0·09	240	0·04	17
August 1. 12 30								
2. 1 12	18·10	2·87	0·09	25	0·12	244	0·03	67
2. 13 49								
3. 2 26	17·73	3·70	0·04	204	0·09	271	0·03	88
3. 14 53								
4. 3 19	17·92	4·80	0·08	206	0·16	258	0·01	333
4. 15 44								
5. 4 4	18·17	5·52	0·05	259	0·08	246	0·08	34
5. 16 30								
6. 4 54	18·15	6·66	0·18	168	0·23	187	0·05	91
6. 17 12								
7. 5 32	18·29	7·58	0·17	121	0·21	206	0·03	331
7. 17 52								
8. 6 15	18·32	7·86	0·29	137	0·14	208	0·13	343
8. 18 39								
9. 7 0	18·18	7·90	0·33	172	0·14	226	0·09	11
9. 19 21								
10. 7 45	18·08	7·27	0·28	159	0·18	206	0·14	333
10. 20 3								
11. 8 29	17·96	6·30	0·29	169	0·19	198	0·12	337
11. 20 56								
12. 9 19	17·99	5·16	0·19	194	0·14	192	0·05	348
12. 21 51	17·83	4·14	0·05	151	0·08	232	0·09	359
13. 10 30								
13. 23 9	17·58	3·26	0·11	275	0·13	290	0·08	90
14. 11 55								
15. 0 40	17·64	2·90	0·06	217	0·05	241	0·05	93
15. 13 21								
16. 2 2	17·73	3·28	0·09	268	0·10	282	0·02	297
16. 14 32								
17. 3 2	17·95	3·81	0·05	254	0·01	268	0·02	350
17. 15 23								
18. 3 48	17·99	4·29	0·05	117	0·06	219	0·02	238
18. 16 3								
19. 4 24	18·12	4·88	0·08	149	0·13	167	0·04	302
19. 16 44								
20. 4 58	18·12	5·47	0·16	166	0·11	244	0·04	338
20. 17 8								
21. 5 24	17·82	5·87	0·08	150	0·08	236	0·06	8
21. 17 40								
22. 5 52	17·54	6·02	0·11	166	0·07	200	0·08	352
22. 18 8								
23. 6 26	17·91	6·00	0·14	155	0·11	248	0·08	322

Height of the Water in each individual tide at Galway, excluding diurnal tide.

Analysed time of high water, corresponding to $p=90°$.	A_2.	C_1.	C_2.	e_2.	C_3.	e_3.	C_4.	e_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
June 24. 18 32	18·59	5·40	0·07	106	0·47	177	0·06	149
25. 6 42								
25. 19 4	17·84	5·46	0·17	173	0·06	231	0·14	352
26. 7 18								
26. 19 40	17·44	5·06	0·21	183	0·07	175	0·08	354
27. 7 59								
27. 20 20	17·74	4·40	0·18	200	0·15	199	0·14	24
28. 8 40								
28. 21 4	17·39	3·94	0·14	214	0·06	169	0·20	331
29. 9 21								
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
30. 22 36	17·70	3·12	0·09	188	0·08	217	0·13	297
July 1. 11 11								
1. 23 46	17·58	2·98	0·02	162	0·16	206	0·07	188
2. 12 22								
3. 0 57	17·94	3·13	0·07	233	0·11	247	0·08	347
3. 13 32								
4. 2 7	18·51	3·59	0·08	140	0·07	245	0·05	170
4. 14 32								
5. 2 57	17·56	4·22	0·08	226	0·19	235	0·04	22
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
6. 16 14	17·98	5·58	0·09	96	0·05	237	0·08	316
7. 4 41								
7. 17 4	18·09	6·34	0·06	156	0·30	208	0·12	336
8. 5 22								
8. 17 37	17·91	7·03	0·06	90	0·11	203	0·12	2
9. 5 57								
9. 18 24	17·87	7·32	0·18	158	0·25	223	0·27	28
10. 6 48								
10. 19 8	17·91	7·38	0·27	178	0·18	249	0·18	358
11. 7 32								
11. 19 55	17·72	6·99	0·29	177	0·06	221	0·25	359
12. 8 18								
12. 20 45	17·60	6·18	0·28	186	0·28	193	0·19	347
13. 9 9								
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
14. 22 40	17·13	4·60	0·16	226	0·25	254	0·13	26
15. 11 15								
15. 23 50	17·61	3·87	0·22	263	0·16	1	0·06	64
16. 12 24								
17. 0 58	17·71	3·67	0·27	215	0·21	221	0·07	101
17. 13 37								
18. 2 15	17·61	3·88	0·06	210	0·19	246	0·08	61
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
19. 15 37	17·52	4·82	0·03	112	0·04	202	0·09	48
20. 4 5								
20. 16 26	17·31	5·22	0·05	117	0·11	207	0·15	32
21. 4 44								
21. 17 3	17·36	5·72	0·14	185	0·07	223	0·17	13
22. 5 19								
22. 17 33	17·43	5·86	0·17	143	0·20	194	0·23	317
23. 5 50								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 5	17·33	6·01	0·20	162	0·22	208	0·11	331
24. 6 21								
24. 18 34	17·32	5·88	0·18	131	0·07	166	0·21	308
25. 6 54								
25. 19 7	17·22	5·52	0·27	149	0·08	226	0·15	339
26. 7 25								
26. 19 33	16·96	5·20	0·12	201	0·21	203	0·08	319
27. 7 49								
27. 20 12	16·98	4·65	0·18	193	0·18	182	0·05	340
28. 8 27								
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
29. 21 33	17·09	3·50	0·21	162	0·18	239	0·14	312
30. 10 6								
30. 22 39	17·04	2·87	0·06	241	0·09	239	0·14	56
31. 11 20								
August 1. 0 0	17·25	2·72	0·03	284	0·08	213	0·02	15
1. 12 39								
2. 1 18	17·66	3·12	0·05	128	0·13	243	0·02	321
2. 13 50								
3. 2 22	17·37	3·93	0·07	174	0·11	245	0·02	99
3. 14 48								
4. 3 14	17·62	4·95	0·08	139	0·20	247	0·07	302
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
5. 16 26	18·05	6·84	0·16	150	0·23	187	0·11	1
6. 4 50								
6. 17 18	18·02	7·93	0·30	118	0·32	200	0·16	4
7. 5 38								
7. 17 59	17·93	8·13	0·25	145	0·25	195	0·20	9
8. 6 22								
8. 18 51	17·77	8·24	0·43	183	0·25	202	0·25	344
9. 7 12								
9. 19 34	17·62	7·65	0·29	160	0·30	216	0·26	7
10. 7 58								
10. 20 13	17·56	6·50	0·40	168	0·29	199	0·21	342
11. 8 39								
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
12. 22 3	17·21	4·52	0·09	166	0·22	200	0·04	83
13. 10 43								
13. 23 22	17·20	3·43	0·13	259	0·11	276	0·09	124
14. 12 7								
15. 0 52	17·12	3·05	0·02	27	0·05	198	0·10	116
15. 13 33								
16. 2 14	17·23	3·38	0·03	234	0·16	290	0·05	314
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
17. 15 35	17·43	4·46	0·02	154	0·11	188	0·09	291
18. 3 59								
18. 16 15	17·79	5·18	0·16	127	0·14	175	0·18	277
19. 4 36								
19. 16 51	17·66	5·67	0·18	160	0·17	209	0·09	53
20. 5 5								
20. 17 15	17·37	6·18	0·13	154	0·07	213	0·10	330
21. 5 31								
21. 17 43	17·06	6·30	0·19	163	0·11	159	0·25	348
22. 5 53								
22. 18 6	17·49	6·22	0·26	148	0·11	204	0·27	313
23. 6 24								

Height of the Water in each individual tide at Old Head, excluding diurnal tide,

Analysed time of high water, corresponding to $p = 90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 17 15	18·51	5·11	0·12	133	0·08	331	0·08	298
23. 5 39								
23. 18 3	18·55	5·04	0·16	146	0·09	23	0·05	315
24. 6 23								
24. 18 40	18·49	4·73	0·12	207	0·17	222	0·09	44
25. 6 50								
25. 19 13	17·88	4·69	0·08	186	0·07	197	0·07	185
26. 7 27								
26. 20 3	17·53	4·40	0·12	192	0·03	28	0·08	342
27. 8 22								
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
28. 21 27	17·73	3·58	0·09	356	0·06	174	0·02	116
29. 9 50								
29. 22 12	17·65	3·07	0·06	348	0·09	160	0·03	60
30. 10 32								
30. 22 52	17·91	2·68	0·04	276	0·12	173	0·02	328
July 1. 11 25								
1. 23 58	17·69	2·52	0·08	207	0·09	195	0·05	210
2. 12 35								
3. 1 12	18·02	2·65	0·05	98	0·06	230	0·04	244
3. 13 43								
4. 2 14	18·68	3·08	0·05	218	0·10	231	0·02	39
4. 14 42								
5. 3 9	17·86	3·71	0·12	161	0·15	280	0·04	57
5. 15 21								
6. 3 55	17·43	4·12	0·19	327	0·16	293	0·15	220
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
7. 17 12								
8. 5 30	18·05	5·43	0·09	332	0·21	213	0·07	339
8. 17 52								
9. 6 12	18·23	6·12	0·13	93	0·14	222	0·09	316
9. 18 36								
10. 7 0	18·22	6·52	0·21	112	0·15	159	0·11	276
10. 19 18								
11. 7 42	18·15	6·29	0·12	194	0·17	186	0·05	303
11. 20 7								
12. 8 30	17·93	6·13	0·15	233	0·08	358	0·02	335
12. 20 56								
13. 9 20	17·83	5·41	0·16	167	0·01	128	0·03	245
13. 21 51	17·31	4·93	0·08	264	0·02	169	0·08	278
14. 10 19								
14. 22 47	17·52	4·07	0·10	206	0·08	270	0·06	267
15. 11 22								
15. 23 56	18·10	3·47	0·10	273	0·15	314	0·03	175
16. 12 32								
17. 1 7	18·08	3·21	0·16	249	0·25	275	0·11	215
17. 13 44								
18. 2 21	17·95	3·37	0·11	178	0·07	251	0·04	356
18. 14 52								
19. 3 23	17·88	3·91	0·02	326	0·16	289	0·07	21
19. 15 44								
20. 4 11	17·83	4·18	0·08	10	0·17	237	0·05	167
20. 16 35								
21. 4 53	17·61	4·59	0·04	120	0·07	279	0·04	113
21. 17 14								
22. 5 30	17·56	4·93	0·07	201	0·11	292	0·07	227
22. 17 44								
23. 6 1	17·61	5·10	0·05	112	0·07	272	0·06	311

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 15	17·57	5·09	0·06	147	0·13	195	0·08	259
24. 6 31								
24. 18 44	17·72	5·10	0·18	118	0·05	127	0·02	273
25. 7 4								
25. 19 20	17·51	4·81	0·15	151	0·09	72	0·03	240
26. 7 37								
26. 19 51	17·42	4·52	0·12	189	0·05	110	0·08	254
27. 8 7								
27. 20 30	17·42	3·83	0·18	184	0·18	118	0·06	284
28. 8 45								
28. 21 15	17·26	3·63	0·07	139	0·11	124	0·09	138
29. 9 39								
29. 22 3	17·35	2·95	0·06	156	0·01	267	0·05	158
30. 10 30								
30. 22 57	17·29	2·47	0·02	208	0·09	267	0·05	12
31. 11 26								
August 1. 0 15	17·56	2·30	0·04	204	0·19	267	0·01	6
1. 12 57								
2. 1 38	17·85	2·57	0·15	201	0·29	275	0·12	91
2. 14 12								
3. 2 46	17·55	3·32	0·10	257	0·27	282	0·08	281
3. 15 2								
4. 3 18	17·64	4·12	0·10	206	0·11	248	0·09	262
4. 15 49								
5. 4 9	18·32	4·97	0·15	33	0·10	242	0·12	220
5. 16 32								
6. 4 56	18·20	5·96	0·08	51	0·13	260	0·13	337
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8. 19 5								
9. 7 26	17·98	7·13	0·17	167	0·07	120	0·10	180
9. 19 45								
10. 8 9	17·92	6·55	0·15	171	0·07	324	0·07	268
10. 20 28								
11. 8 54	17·66	5·75	0·12	148	0·02	33	0·01	183
11. 21 19								
12. 9 42	17·70	4·86	0·07	198	0·03	157	0·06	103
12. 22 10	17·57	3·71	0·21	199	0·26	229	0·05	253
13. 10 47								
13. 23 23	17·44	3·00	0·06	225	0·13	238	0·03	83
14. 12 11								
15. 0 58	17·33	2·48	0·08	289	0·18	276	0·03	157
15. 13 37								
16. 2 16	17·52	2·67	0·13	172	0·19	270	0·02	13
16. 14 50								
17. 3 23	17·79	3·36	0·04	359	0·16	277	0·06	27
17. 15 36								
18. 4 5	17·69	3·98	0·08	308	0·06	216	0·01	93
18. 16 26								
19. 4 47	17·90	4·52	0·09	107	0·02	75	0·09	169
19. 17 3								
20. 5 17	18·07	5·03	0·17	79	0·07	278	0·03	134
20. 17 51								
21. 6 7	17·18	5·27	0·31	266	0·03	159	0·10	194
21. 18 12								
22. 6 24	17·67	5·52	0·27	70	0·13	91	0·12	257
22. 18 38								
23. 6 56	17·69	5·28	0·03	155	0·09	73	0·04	310

Height of the Water in each individual tide at Mullaghmore, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 17 45	18·44	4·98	0·17	246	0·04	72	0·08	189
23. 5 45								
23. 18 17	18·85	4·97	0·18	187	0·14	65	0·13	237
24. 6 39								
24. 18 46	19·12	4·77	0·17	27	0·25	274	0·33	108
25. 6 56								
25. 19 34	18·29	4·51	0·19	265	0·18	16	0·07	328
26. 7 48								
26. 20 10	18·01	4·10	0·13	157	0·15	30	0·10	261
27. 8 29								
27. 20 50	18·20	3·77	0·04	228	0·11	60	0·02	175
28. 9 7								
28. 21 24	18·25	3·32	0·16	115	0·12	327	0·07	282
29. 9 49								
29. 22 14	18·08	2·90	0·11	126	0·10	283	0·06	131
30. 10 40								
30. 23 6	18·33	2·56	0·09	224	0·02	244	0·12	204
July 1. 11 51								
2. 0 36	18·46	2·51	0·09	95	0·12	234	0·05	50
2. 13 3								
3. 1 29	18·35	2·46	0·04	178	0·08	160	0·05	315
3. 14 8								
4. 2 46	18·97	2·87	0·22	358	0·10	151	0·05	18
4. 15 3								
5. 3 21	18·26	3·35	0·11	321	0·13	250	0·07	22
5. 15 35								
6. 4 19	17·96	3·88	0·04	149	0·04	126	0·05	265
6. 16 37								
7. 5 4	18·87	4·27	0·26	129	0·19	355	0·04	264
7. 17 18								
8. 5 36	18·42	5·11	0·33	291	0·19	275	0·11	171
8. 17 59								
9. 6 19	18·73	5·77	0·10	172	0·09	28	0·12	173
9. 18 53								
10. 7 17	18·65	6·02	0·22	166	0·19	16	0·08	260
10. 19 30								
11. 7 54	18·57	5·89	0·13	148	0·05	64	0·10	238
11. 20 18								
12. 8 41	18·01	5·68	0·15	204	0·17	56	0·06	188
12. 21 10	18·04	5·41	0·05	333	0·24	33	0·06	44
13. 9 38								
13. 22 6	17·61	4·59	0·17	241	0·13	45	0·08	204
14. 10 32								
14. 22 57	17·73	3·92	0·11	156	0·16	121	0·15	212
15. 11 32								
16. 0 6	18·15	3·16	0·25	276	0·12	152	0·09	246
16. 12 44								
17. 1 22	18·27	3·12	0·21	158	0·10	81	0·04	151
17. 14 5								
18. 2 47	18·22	3·15	0·09	176	0·04	68	0·02	112
18. 15 17								
19. 3 46	18·05	3·40	0·10	274	0·14	58	0·12	56
19. 16 12								
20. 4 39	18·09	3·73	0·14	254	0·12	227	0·05	199
20. 16 57								
21. 5 15	18·03	4·21	0·01	128	0·04	75	0·02	51
21. 17 42								
22. 5 58	17·68	4·50	0·30	223	0·17	217	0·17	176
22. 18 3								
23. 6 20	17·87	4·85	0·07	51	0·13	46	0·07	192

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 39	17·91	5·01	0·05	78	0·16	41	0·05	142
24. 6 55								
24. 19 11	17·99	4·81	0·19	117	0·10	298	0·04	120
25. 7 31								
25. 19 40	17·62	4·65	0·14	240	0·16	59	0·12	207
26. 7 57								
26. 20 14	17·63	4·18	0·13	114	0·11	30	0·05	159
27. 8 30								
27. 20 51	17·77	3·80	0·07	180	0·08	352	0·08	179
28. 9 4								
28. 21 17	17·57	3·56	0·09	101	0·07	73	0·15	68
29. 9 45								
29. 22 12	17·64	2·82	0·04	190	0·09	136	0·05	324
30. 10 38								
30. 23 4	17·50	2·19	0 02	150	0·01	130	0·08	212
31. 11 49								
August 1. 0 33	17·71	2·07	0·04	157	0·05	139	0·03	336
1. 13 20								
2. 2 6	18·24	2·45	0·05	232	0·06	113	0·04	30
2. 14 36								
3. 3 5	17·93	3·15	0·11	168	0·17	253	0·05	225
....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
4. 16 20	18·40	4·69	0 05	337	0·06	14	0·05	152
5. 4 40								
5. 17 12	18·64	5·53	0·26	112	0·09	298	0·04	62
6. 5 36								
6. 17 56	18·73	6·18	0·12	84	0·14	301	0·08	90
7. 6 16								
7. 18 17	18·13	6·54	0·41	340	0·18	227	0·25	127
8. 6 40								
8. 19 15	18·30	6·68	0·27	174	0·13	51	0·15	214
9. 7 36								
9. 19 59	18·54	6·29	0·33	138	0·17	26	0·10	194
10. 8 23								
10. 20 49	17·97	5·57	0·16	233	0·19	38	0·09	241
11. 9 13								
11. 21 36	18·15	4·71	0·07	202	0 16	49	0·10	220
12. 10 2								
12. 22 27	18·02	3·62	0·10	263	0·10	75	0·11	227
13. 11 7								
13. 23 47	17·79	2·88	0·05	220	0·18	164	0·09	245
14. 12 31								
15. 1 14	17·64	2·31	0·10	181	0·09	175	0·12	37
15. 13 58								
16. 2 41	17·70	2 72	0·08	225	0·07	208	0·13	3
16. 15 10								
17. 3 38	17·99	3·27	0·08	212	0·06	97	0·05	96
17. 15 56	17·99	3·73	0·07	257	0·05	211	0·11	190
18. 4 12								
18. 16 42	18·26	4·18	0·02	188	0·13	9	0·10	293
19. 5 3								
19. 17 15	18·52	4·53	0·03	320	0·16	352	0·03	5
20. 5 29								
20. 17 26	17·61	4·79	0·29	216	0·15	170	0·12	184
21. 5 42								
21. 18 29	17·89	5 39	0·29	121	0·26	1	0·07	52
22. 6 41								
22. 19 45	17·86	5·32	0·26	217	0·06	101	0·15	134
23. 8 3								

Height of the Water in each individual tide at Buncrana, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 18 2	17·23	5·28	0·18	184	0·12	263	0·04	113
23. 6 18								
23. 18 38	18·38	5·10	0·16	145	0·19	234	0·06	158
24. 6 51								
24. 19 23	18·22	5·10	0·12	215	0·16	266	0·05	259
25. 7 38								
25. 20 3	17·93	4·69	0·11	123	0·12	263	0·03	158
26. 8 20								
26. 20 35	17·44	4·37	0·20	161	0·09	281	0·05	282
27. 9 7								
27. 21 15	17·66	3·69	0·13	203	0·15	248	0·07	230
28. 9 20								
28. 22 0	17·47	3·22	0·09	164	0·11	256	0·00	74
29. 10 25								
29. 22 48	17·40	2·97	0·15	54	0·03	203	0·04	143
30. 11 17								
30. 23 46	17·71	2·64	0·15	79	0·04	244	0·03	203
July 1. 12 20								
2. 0 54	17·52	2·42	0·12	100	0·07	243	0·02	260
2. 13 32								
3. 2 10	17·70	2·58	0·12	128	0·01	264	0·01	322
3. 14 44								
4. 3 18	18·18	3·04	0·17	186	0·11	322	0·02	97
4. 15 48								
5. 4 3	17·79	3·39	0·22	261	0·05	199	0·06	159
5. 16 26								
6. 5 4	17·06	4·18	0·08	280	0·05	300	0·03	279
6. 17 24								
7. 5 37	17·55	4·94	0·08	289	0·09	252	0·04	167
7. 18 4								
8. 6 29	17·70	5·75	0·10	193	0·05	283	0·03	221
8. 18 52								
9. 7 16	17·78	6·25	0·23	153	0·17	261	0·04	340
9. 19 33								
10. 8 0	17·85	6·57	0·28	163	0·11	322	0·09	296
10. 20 21								
11. 8 45	17·98	6·56	0·29	152	0·08	237	0·11	253
11. 21 11								
12. 9 29	17·32	6·10	0·24	177	0·04	253	0·11	328
12. 22 5	17·31	5·79	0·26	215	0·15	265	0·07	241
13. 10 33								
13. 23 0	16·99	4·91	0·15	253	0·13	296	0·07	290
14. 11 31								
15. 0 2	16·81	4·06	0·13	227	0·02	359	0·02	208
15. 12 38								
16. 1 13	17·31	3·31	0·09	204	0·07	320	0·02	132
16. 13 55								
17. 2 36	17·53	3·15	0·07	177	0·03	263	0·05	143
17. 15 15								
18. 3 54	17·28	3·32	0·21	211	0·03	162	0·00	29
18. 16 22								
19. 5 2	17·29	3·70	0·07	269	0·02	26	0·04	287
19. 17 19								
20. 5 43	17·28	4·12	0·01	78	0·06	241	0·03	325
20. 18 5								
21. 6 22	17·16	4·61	0·10	137	0·03	311	0·06	207
21. 18 39								
22. 6 56	17·04	5·02	0·09	159	0·08	246	0·04	238
22. 19 10								
23. 7 24	17·16	5·21	0·12	106	0·08	256	0·05	345

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 19 41	17·21	5·23	0·12	149	0·07	216	0·08	264
24. 7 53								
24. 20 3	17·26	5·11	0·14	118	0·09	224	0·03	259
25. 8 20								
25. 20 37	16·96	4·87	0·05	108	0·07	194	0·01	325
26. 8 44								
26. 21 3	16·87	4·41	0·03	135	0·06	213	0·02	306
27. 9 23								
27. 21 38	17·04	3·87	0·05	159	0·07	217	0·02	266
28. 9 51								
28. 22 9	16·82	3·53	0·04	311	0·13	247	0·04	235
29. 10 29								
29. 22 49	17·02	2·86	0·11	58	0·08	234	0·02	179
30. 11 18								
30. 23 46	17·06	2·41	0·12	27	0·06	190	0·02	15
31. 12 31								
August 1. 1 16	17·24	2·25	0·14	126	0·01	284	0·01	95
1. 14 1								
2. 2 45	17·68	2·63	0·18	189	0·10	225	0·05	234
2. 15 9								
3. 3 45	17·24	3·10	0·14	227	0·04	216	0·03	53
3. 16 13								
4. 4 36	17·60	3·87	0·05	292	0·09	195	0·05	199
4. 17 3								
5. 5 23	17·79	5·20	0·14	249	0·08	233	0·08	272
5. 17 43								
6. 6 4	17·77	6·20	0·12	210	0·06	102	0·14	294
6. 18 27								
7. 6 42	17·82	6·90	0·10	189	0·06	258	0·02	237
7. 19 6								
8. 7 31	17·67	7·42	0·25	151	0·34	280	0·08	56
8. 19 49								
9. 8 11	17·71	7·40	0·25	178	0·11	285	0·12	309
9. 20 32								
10. 8 53	17·71	6·68	0·26	168	0·12	300	0·08	313
10. 21 16								
11. 9 37	17·37	5·76	0·29	158	0·09	293	0·10	294
11. 22 16	17·22	4·92	0·03	254	0·06	328	0·03	310
12. 10 43								
12. 23 10	17·32	3·62	0·10	244	0·09	266	0·04	313
13. 11 50								
14. 0 30	17·09	2·76	0·08	146	0·06	325	0·03	154
14. 13 17								
15. 2 3	16·96	2·30	0·13	208	0·04	69	0·01	315
15. 14 43								
16. 3 22	16·99	2·81	0·11	217	0·03	90	0·02	96
16. 15 53								
17. 4 18	17·46	3·32	0·01	172	0·06	244	0·04	165
17. 16 48								
18. 5 4	17·37	3·88	0·01	169	0·03	196	0·03	209
18. 17 22								
19. 5 39	17·54	4·52	0·09	161	0·07	273	0·02	9
19. 17 52								
20. 6 4	17·70	5·04	0·01	202	0·06	185	0·05	235
20. 18 22								
21. 6 37	17·33	5·38	0·17	156	0·08	213	0·06	237
21. 18 49								
22. 7 4	17·11	5·50	0·17	129	0·08	266	0·09	330
22. 19 15								
23. 7 36	17·67	5·46	0·06	148	0·05	292	0·05	302

Height of the Water in each individual tide at Port Rush, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 18 35	17·91	2·38	0·05	195	0·10	266	0·04	163
23. 6 51								
23. 19 3	18·62	2·22	0·03	229	0·14	251	0·05	132
24. 7 16								
24. 19 37	18·64	2·21	0·06	185	0·14	250	0·03	342
25. 7 52								
25. 20 16	18·26	1·89	0·05	141	0·12	267	0·03	323
26. 8 33								
26. 20 21	17·66	1·62	0·08	154	0·08	248	0·02	313
27. 8 56								
27. 21 43	17·92	1·39	0·11	221	0·12	239	0·01	171
28. 9 48								
28. 22 30	17·52	1·20	0·09	255	0·10	247	0·02	117
29. 10 55								
29. 23 30	17·41	1·03	0·08	324	0·12	290	0·04	226
30. 12 30								
July 1. 0 39	17·95	0·87	0·07	84	0·05	310	0·00	156
1. 13 23								
2. 2 7	17·86	0·94	0·14	161	0·06	310	0·02	106
2. 14 58								
3. 3 48	17·93	1·13	0·11	172	0·04	338	0·01	66
3. 16 12								
4. 4 36	18·46	1·38	0·15	215	0·07	315	0·02	117
4. 16 57								
5. 5 18	18·10	1·57	0·12	239	0·11	274	0 05	155
5. 17 8								
6. 5 46	17·35	1·76	0·06	223	0·12	252	0·04	104
6. 17 49								
7. 6 2	17·88	2·26	0·12	283	0·10	243	0·03	176
7. 18 27								
8. 6 52	18·00	2·60	0·06	193	0·15	274	0·02	150
8. 19 0								
9. 7 24	18·15	2·80	0·15	164	0 07	270	0·01	314
9. 19 38								
10. 8 5	18·28	2·90	0·14	158	0·14	265	0·02	334
10. 20 28								
11. 8 51	18·29	2·91	0·15	155	0·16	258	0·02	162
11. 21 12								
12. 9 30	17·83	2·58	0·18	143	0·11	260	0·01	355
12. 21 52								
13. 10 18	18·15	2·17	0·22	153	0·11	227	0·01	56
13. 22 47								
14. 11 25	17·37	1·72	0·21	150	0·09	254	0·02	105
15. 0 29	17·04	1·52	0·14	282	0·09	314	0·04	158
15. 13 12								
16. 1 55	17·52	1·21	0·07	276	0·05	335	0·04	169
16. 14 39								
17. 3 23	17·73	1·31	0·06	237	0 03	322	0·06	206
17. 15 58								
18. 4 32	17·51	1·41	0·14	227	0·08	285	0·01	156
18. 16 57								
19. 5 22	17·41	1·68	0·13	277	0·06	312	0·02	189
19. 17 40								
20. 6 4	17·56	1·82	0·01	29	0·06	274	0·02	176
20. 18 15								
21. 6 32	17·57	2·00	0·05	69	0·13	287	0·00	180
21. 18 46								
22. 7 23	17·47	2·14	0·02	56	0·12	275	0·01	253
22. 19 19								
23. 7 33	17·57	2·22	0·11	116	0·11	274	0·03	285

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 19 31	17·57	2·33	0·12	346	0·20	240	0·08	141
24. 7 43								
24. 20 10	17·52	2·15	0·06	85	0·14	261	0·03	157
25. 8 27								
25. 20 49	17·37	1·98	0·04	201	0·13	256	0·02	144
26. 8 56								
26. 21 15	17·22	1·70	0·01	61	0·10	252	0·02	135
27. 9 35								
27. 21 57	17·38	1·39	0·02	70	0·10	246	0·04	239
28. 10 10								
28. 22 49	17·06	1·17	0·07	31	0·10	256	0 03	126
29. 11 16								
29. 23 43	17·18	0·93	0·10	64	0·05	310	0·01	183
30. 12 29								
31. 1 15	17·40	0·80	0·15	78	0·03	323	0·02	330
31. 14 11								
August 1. 3 6	17·43	0·94	0·17	173	0·06	329	0·00	17
1. 15 41								
2. 4 16	17·84	1·30	0·10	201	0·09	305	0·03	241
2. 16 20								
3. 4 56	17·34	1·39	0·20	260	0·08	222	0·04	173
3. 17 8								
4. 5 31	17·77	1·79	0·16	273	0·11	254	0·04	184
4. 17 42								
5. 6 2	18·16	2·28	0·15	267	0·17	242	0·05	242
5. 18 11								
6. 6 32	18·00	2·72	0·08	201	0·16	239	0·03	129
6. 18 47								
7. 7 2	18·19	3·17	0·07	179	0·20	245	0·03	322
7. 19 19								
8. 7 44	18·06	3·48	0·23	144	0·13	248	0·03	307
8. 19 59								
9. 8 21	18·03	3·32	0·20	161	0·10	250	0·02	321
9. 20 45								
10. 9 6	17·91	2·91	0·20	155	0·14	247	0·03	226
10. 21 27								
11. 9 48	17·57	2·37	0·21	144	0·11	266	0·02	310
11. 22 19								
12. 10 54	17·83	1·62	0·19	154	0·12	257	0·02	39
13. 0 1	17·58	1·27	0·11	319	0·06	302	0·04	163
13. 12 55								
14. 1 49	17·39	1·00	0·07	239	0·04	7	0·03	208
14. 14 35								
15. 3 21	17·23	1·06	0·10	244	0·01	82	0·04	181
15. 15 55								
16. 4 28	17·21	1·30	0·06	261	0·06	330	0·03	215
16. 16 50								
17. 5 15	17·68	1·46	0·06	77	0·09	300	0·03	239
17. 17 33								
18. 5 49	17·62	1·67	0·02	67	0·09	293	0·04	56
18. 18 2								
19. 6 19	17·88	2·03	0·04	173	0·11	277	0·03	187
19. 18 13								
20. 6 25	18·16	2·16	0·09	125	0·18	226	0·06	305
20. 18 45								
21. 7 0	17·60	2·28	0·04	140	0·12	251	0·04	199
21. 19 17								
22. 7 32	17·36	2·42	0·06	129	0·11	286	0·02	215
22. 19 43								
23. 7 57	17·89	2·29	0·04	288	0·11	262	0·03	225

Height of the Water in each individual tide at Carrowkeel, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 19 42	18·10	3·11	0·13	94	0·05	146	0·06	349
23. 7 58								
23. 20 29	18·69	2·90	0·03	23	0·06	210	0·05	206
24. 8 42								
24. 21 7	18·58	2·95	0·03	276	0·06	223	0·01	314
25. 9 22								
25. 21 29	18·26	2·70	0·08	97	0·05	182	0·02	37
26. 9 46								
26. 21 50	17·82	2·42	0·05	152	0·07	169	0·02	247
27. 10 22								
27. 22 42	17·90	2·15	0·18	208	0·07	198	0·03	305
28. 10 47								
28. 23 3	17·92	2·02	0·10	28	0·09	157	0·05	192
29. 11 34								
30. 0 4	17·98	1·60	0·12	5	0·06	161	0·01	57
30. 12 36								
July 1. 1 8	18·34	1·39	0·21	58	0·05	188	0·03	269
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
3. 4 4	18·35	1·58	0·21	125	0·12	221	0·04	33
3. 16 13	18·58	1·61	0·07	211	0·15	220	0·08	45
4. 4 49								
4. 17 14	18·54	2·15	0·09	207	0·12	194	0·03	157
5. 5 29								
5. 17 45	17·75	2·54	0·07	225	0·11	169	0·03	346
6. 6 22								
6. 18 45	18·41	2·99	0·10	269	0·12	222	0·04	49
7. 6 58								
7. 19 28	18·61	3·50	0·10	13	0·14	235	0·06	346
8. 7 53								
8. 20 5	18·52	3·60	0·09	179	0·05	196	0·02	341
9. 8 29								
9. 20 54	18·36	3·80	0·12	252	0·09	198	0·06	97
10. 9 23								
10. 21 52	18·48	3·80	0·25	248	0·11	209	0·06	218
11. 10 13								
11. 22 34	17·91	3·52	0·16	234	0·05	171	0·09	60
12. 10 57								
12. 23 20	18·02	3·25	0·19	270	0·07	279	0·03	172
13. 11 47								
14. 0 14	17·46	2·69	0·23	290	0·04	290	0·09	123
14. 12 45								
15. 1 15	17·41	2·21	0·17	283	0·03	116	0·06	86
15. 13 50								
16. 2 25	17·99	1·88	0·09	291	0·03	343	0·06	145
16. 15 5								
17. 3 45	18·46	1·92	0·08	112	0·05	323	0·03	281
17. 16 22	18·40	2·06	0·13	139	0·06	193	0·05	178
18. 5 5								
18. 17 32	18·24	2·33	0·12	278	0·05	239	0·05	312
19. 6 12								
19. 18 25	18·14	2·58	0·08	101	0·10	228	0·10	9
20. 6 49								
20. 19 7	18·01	2·80	0·08	169	0·11	183	0·06	74
21. 7 24								
21. 19 35	17·92	2·97	0·07	349	0·17	200	0·00	115
22. 7 52								
22. 20 14	17·98	3·09	0·03	217	0·12	203	0·05	288
23. 8 28								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 20 46	17·92	2·95	0·04	231	0·17	197	0·03	230
24. 8 58								
24. 21 8	17·96	2·88	0·07	101	0·13	197	0·01	5
25. 9 25								
25. 21 43	17·79	2·82	0·02	342	0·10	166	0·03	75
26. 9 56								
26. 22 9	17·55	2·62	0·15	316	0·08	181	0·00	218
27. 10 28								
27. 22 47	17·60	2·24	0·07	266	0·09	201	0·02	255
28. 11 4								
28. 23 21	17·56	1·92	0·08	307	0·08	201	0·01	65
29. 11 44								
30. 0 6	17·50	1·62	0·15	9	0·14	169	0·04	179
30. 12 42								
31. 1 17	17·69	1·30	0·20	20	0·08	187	0·05	197
31. 14 15								
August 1. 3 13	17·97	1·42	0·33	119	0·03	222	0·03	293
1. 15 30								
2. 3 56	17·98	1·67	0·25	207	0·13	156	0·05	90
2. 16 30								
3. 5 6	17·79	1·92	0·19	218	0·06	163	0·03	289
3. 17 39								
4. 6 2	18·22	2·52	0·14	255	0·13	188	0·04	9
4. 18 43								
5. 7 3	18·39	3·67	0·14	242	0·18	202	0·03	26
5. 19 15								
6. 7 36	18·43	3·67	0·12	187	0·11	208	0·02	104
6. 19 53								
7. 8 8	18·59	4·04	0·10	323	0·12	205	0·04	121
7. 20 39								
8. 9 4	18·60	4·21	0·12	144	0·17	201	0·11	337
8. 21 33	18·42	4·16	0·22	224	0·22	202	0·04	342
9. 9 55								
9. 22 17	18·23	3·80	0·16	248	0·19	227	0·13	211
10. 10 35								
10. 22 52	17·79	3·32	0·10	257	0·17	215	0·02	356
11. 11 18								
11. 23 44	17·76	2·65	0·15	271	0·07	193	0·07	155
12. 12 7								
13. 0 29	17·62	1·95	0·12	305	0·04	201	0·03	131
13. 13 15								
14. 2 1	17·52	1·54	0·05	205	0·03	285	0·02	142
14. 14 50								
15. 3 38	17·60	1·63	0·10	146	0·03	131	0·03	155
15. 16 26								
16. 5 2	17·77	1·78	0·12	106	0·11	226	0·03	212
16. 17 28								
17. 5 53	18·09	2·08	0·05	149	0·05	235	0·01	341
17. 18 13								
18. 6 29	18·07	2·40	0·08	188	0·09	183	0·05	216
18. 18 52								
19. 7 9	18·24	2·72	0·02	224	0·15	228	0·04	189
19. 19 14								
20. 7 26	18·33	3·09	0·09	261	0·14	203	0·07	70
20. 19 50								
21. 8 5	17·93	3·08	0·02	281	0·11	188	0·05	345
21. 20 19								
22. 8 34	17·66	3·18	0·05	47	0·16	176	0·05	99
22. 20 40	18·10	3·10	0·09	149	0·24	178	0·04	110
.....	....	....	....	....	....	....	....	....

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Height of the Water in each individual tide at Ballycastle, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_p.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
June 27. 23 3	17·45	0·95	0·08	2	0·08	260	0·04	156
28. 11 48								
29. 0 34	17·35	0·62	0·18	73	0·09	315	0·04	268
29. 13 20								
30. 2 6	17·24	0·64	0·15	139	0·04	70	0·02	349
30. 15 1								
July 1. 3 56	17·57	0·69	0·09	161	0·00	284	0·05	71
1. 16 3	17·29	0·78	0·17	270	0·05	157	0·04	10
2. 4 21								
2. 16 55	17·30	0·94	0·12	308	0·06	251	0·00	55
3. 5 25								
3. 17 56	17·94	0·94	0·13	341	0·02	3	0·02	46
4. 6 17								
4. 18 15	18·10	0·98	0·14	307	0·06	183	0·05	198
5. 6 24								
5. 18 39	17·16	1·08	0·13	349	0·06	302	0·01	269
6. 6 59								
6. 19 4	17·77	1·33	0·25	318	0·08	281	0·06	276
7. 6 49								
7. 19 13	17·82	1·52	0·06	321	0·15	271	0·06	250
8. 7 22								
8. 19 33	17·88	1·57	0·06	267	0·11	235	0·03	204
9. 7 47								
9. 20 16	18·00	1·62	0·09	232	0·14	252	0·04	133
10. 8 34								
10. 20 45	18·12	1·62	0·05	82	0·14	272	0·06	221
11. 9 10								
11. 21 28	17·59	1·45	0·12	216	0·11	240	0·02	11
12. 9 52								
12. 23 14	17·66	1·32	0·29	314	0·09	359	0·11	205
13. 11 42								
14. 0 9	17·14	0·86	0·27	293	0·19	321	0·10	143
14. 12 41								
15. 1 13	16·87	0·71	0·23	284	0·11	338	0·08	76
15. 14 14								
16. 3 15	17·45	0·70	0·03	37	0·03	23	0·05	261
16. 16 10	17·81	1·02	0·06	115	0·04	276	0·07	209
17. 4 58								
17. 17 23	17·56	1·08	0·10	290	0·03	47	0·03	284
18. 5 48								
18. 18 35	17·48	1·16	0·12	33	0·06	297	0·05	321
19. 6 42								
19. 18 55	17·50	1·13	0·12	40	0·08	323	0·11	299
20. 6 56								
20. 19 6	17·39	1·18	0·10	25	0·10	309	0·06	272
21. 7 13								
21. 19 36	17·30	1·27	0·07	11	0·06	317	0·01	325
22. 7 50								
22. 20 6	17·34	1·29	0·10	28	0·12	293	0·02	291
23. 8 16								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 20 28	17·29	1·24	0·06	2	0·12	300	0·04	234
24. 8 38								
24. 20 49	17·25	1·20	0·13	339	0·14	293	0·04	213
25. 9 9								
25. 21 46	17·11	0·97	0·13	329	0·09	314	0·03	182
26. 10 3								
26. 22 19	16·98	0·83	0·13	342	0·12	319	0·00	250
27. 10 50								
27. 23 21	17·23	0·70	0·08	10	0·10	341	0·02	240
28. 11 51								
29. 0 21	17·06	0·56	0·10	303	0·04	350	0·01	242
29. 13 10								
30. 2 0	17·17	0·63	0·12	113	0·04	171	0·03	343
30. 14 37	17·11	0·78	0·13	192	0·07	153	0·01	109
31. 3 11								
31. 15 24	17·07	0·92	0·19	263	0·05	214	0·03	63
August 1. 4 12								
1. 17 1	17·49	0·91	0·22	317	0·06	281	0·00	273
2. 5 5								
2. 17 57	17·31	0·97	0·09	17	0·04	2	0·02	91
3. 6 19								
3. 18 22	17·78	1·06	0·11	339	0·07	293	0·07	270
4. 6 29								
4. 18 18	18·06	1·36	0·15	315	0·08	199	0·08	227
5. 6 31								
5. 18 49	17·87	1·65	0·09	280	0·13	288	0·05	242
6. 7 6								
6. 19 16	18·11	1·87	0·08	274	0·17	233	0·08	189
7. 7 20								
7. 19 42	17·83	2·09	0·12	240	0·15	244	0·04	202
8. 7 58								
8. 20 26	17·88	1·89	0·10	222	0·10	249	0·04	200
9. 8 47								
9. 21 48	17·58	1·70	0·30	301	0·16	319	0·09	239
10. 10 5								
10. 22 22	17·34	1·26	0·24	303	0·18	297	0·02	23
11. 11 9								
11. 23 55	17·51	0·86	0·21	316	0·13	354	0·05	151
12. 12 41								
13. 1 26	17·59	0·68	0·18	15	0·07	44	0·02	0
13. 14 40	17·54	0·77	0·15	96	0·05	55	0·09	322
14. 4 8								
14. 16 7	17·28	0·97	0·07	315	0·04	311	0·03	106
15. 4 45								
15. 17 20	17·16	0·98	0·11	28	0·04	296	0·06	323
16. 5 46								
16. 17 46	17·52	1·08	0·08	15	0·04	310	0·01	291
17. 6 0								
17. 18 29	17·50	1·12	0·05	358	0·05	347	0·03	273
18. 6 37								
18. 18 55	17·77	1·26	0·05	344	0·10	304	0·01	176
19. 6 55								
19. 19 9	17·98	1·27	0·09	342	0·09	293	0·03	338
20. 7 5								
20. 19 32	17·38	1·34	0·13	337	0·14	288	0·04	230
21. 7 48								
21. 20 20	17·05	1·27	0·13	316	0·09	286	0·04	230
22. 8 31								
22. 20 42	17·57	1·21	0·23	316	0·11	273	0·02	137
.....	....	....	....	....	....	....	....	....

Height of the Water in each individual tide at Glenarm, excluding diurnal tide,

Analyzed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 23. 23 50	18·64	2·75	0·06	74	0·05	205	0·04	318
24. 12 5								
25. 0 20	18·63	2·72	0·08	114	0·08	238	0·01	346
25. 12 38								
26. 0 56	18·15	2·72	0·05	42	0·08	237	0·05	41
26. 13 20								
27. 1 44	17·48	2·61	0·08	96	0·07	260	0·01	235
27. 14 5								
28. 2 26	17·87	2·51	0·12	151	0·03	261	0·03	344
28. 14 50								
29. 3 13	17·58	2·55	0·14	171	0·09	256	0·03	256
29. 15 27	17·32	2·42	0·04	241	0·09	230	0·04	355
30. 3 51								
30. 16 22	17·55	2·30	0·07	220	0·02	265	0·04	11
July 1. 4 47								
1. 17 0	17·59	2·19	0·18	332	0·14	243	0·06	144
2. 5 23								
2. 18 9	17·71	2·20	0·13	12	0·05	249	0·03	189
3. 6 42								
3. 19 15	18·47	2·28	0·12	29	0·08	241	0·01	146
4. 7 42								
4. 20 10	18·31	2·42	0·19	37	0·02	294	0·05	260
5. 8 43								
5. 21 9	17·34	2·65	0·18	72	0·06	186	0·04	282
6. 9 35								
6. 22 3	17·78	2·64	0·12	76	0·08	215	0·02	50
7. 10 19								
7. 22 36	17·99	2·88	0·15	54	0·06	200	0·03	219
8. 10 59								
8. 23 23	17·93	2·87	0·22	75	0·07	224	0·03	306
9. 11 46								
10. 0 9	18·11	2·96	0·24	76	0·15	243	0·05	280
10. 12 32								
11. 0 54	18·30	3·18	0·27	51	0·11	224	0·01	215
11. 13 19								
12. 1 43	17·87	3·03	0·25	81	0·10	229	0·06	314
12. 14 9								
13. 2 35	18·13	2·85	0·28	68	0·07	196	0·02	230
13. 14 52	17·62	3·00	0·22	85	0·05	139	0·03	328
14. 3 17								
14. 15 57	17·13	2·82	0·10	140	0·03	242	0·03	351
15. 4 25								
15. 16 58	17·47	2·62	0·05	257	0·06	243	0·03	76
16. 5 32								
16. 18 0	17·81	2·58	0·03	309	0·03	189	0·03	268
17. 6 27								
17. 19 19	17·64	2·40	0·15	18	0·05	222	0·02	146
18. 8 3								
18. 20 26	17·60	2·58	0·11	74	0·03	271	0·03	252
19. 8 52								
19. 21 6	17·45	2·57	0·09	55	0·07	254	0·03	93
20. 9 36								
20. 22 15	17·30	2·62	0·10	343	0·01	179	0·01	71
21. 10 32								
21. 22 49	17·28	2·70	0·08	38	0·02	243	0·03	75
22. 11 6								
22. 23 23	17·26	2·73	0·07	31	0·04	254	0·02	33
23. 11 41								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 24. 0 0	17·28	2·72	0·06	61	0·05	268	0·03	171
24. 12 17								
25. 0 34	17·34	2·69	0·12	80	0·06	238	0·01	0
25. 12 54								
26. 1 15	17·35	2·66	0·17	112	0·07	267	0·03	37
26. 13 32								
27. 1 49	17·16	2·62	0·12	127	0·07	243	0·04	10
27. 14 4								
28. 2 19	17·23	2·55	0·06	148	0·06	204	0·00	350
28. 14 45								
29. 3 10	16·97	2·34	0·15	131	0·08	279	0·01	110
29. 15 26	17·07	2·30	0·15	212	0·04	189	0·03	65
30. 3 46								
30. 15 56	17·34	2·25	0·12	250	0·04	271	0·03	101
31. 4 29								
31. 17 15	17·48	2·14	0·12	334	0·05	240	0·03	110
August 1. 5 54								
1. 18 39	18·04	2·10	0·16	27	0·04	276	0·02	193
2. 7 4								
2. 19 42	17·86	2·31	0·20	77	0·01	347	0·03	311
3. 8 21								
3. 20 54	18·09	2·63	0·18	86	0·05	276	0·02	290
4. 9 14								
4. 21 37	18·34	2·72	0·13	50	0·07	178	0·01	288
5. 9 56								
5. 22 15	18·10	2·93	0·17	74	0·09	211	0·01	189
6. 10 35								
6. 22 55	18·32	3·14	0·20	61	0·03	211	0·02	206
7. 11 15								
7. 23 35	18·17	3·20	0·29	63	0·13	205	0·04	271
8. 12 0								
9. 0 25	18·19	3·12	0·33	74	0·09	226	0·03	321
9. 12 51								
10. 1 17	18·26	3·15	0·30	75	0·09	221	0·01	1
10. 13 44								
11. 2 12	18·07	2·94	0·30	105	0·13	230	0·03	232
11. 14 36	18·06	3·10	0·13	136	0·07	266	0·02	72
12. 2 58								
12. 15 24	17·89	2·73	0·13	216	0·11	232	0·02	83
13. 3 54								
13. 16 32	17·54	2·55	0·03	214	0·04	237	0·02	106
14. 5 7								
14. 17 40	17·45	2·12	0·06	329	0·02	307	0·01	97
15. 6 25								
15. 19 6	17·35	2·22	0·09	39	0·04	208	0·02	88
16. 7 43								
16. 20 10	17·74	2·32	0·07	64	0·02	181	0·04	169
17. 8 40								
17. 21 16	17·71	2·41	0·12	24	0·01	293	0·02	355
18. 9 34								
18. 21 51	17·95	2·68	0·09	16	0·09	205	0·04	48
19. 10 12								
19. 22 32	18·20	2·58	0·10	52	0·05	198	0·03	96
20. 10 48								
20. 23 4	17·69	2·70	0·09	116	0·07	227	0·01	247
21. 11 19								
21. 23 33	17·25	2·70	0·08	78	0·04	232	0·03	43
22. 11 49								
23. 0 4	17·76	2·72	0·13	109	0·04	174	0·07	294
.....	....	....	....	....	....	....	....	....

Height of the Water in each individual tide at Donaghadee, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 23 23	18·22	4·78	0·14	72	0·07	161	0·01	221
23. 11 45								
24. 0 7	18·70	4·90	0·06	325	0·03	221	0·02	61
24. 12 25								
25. 0 43	18·78	4·86	0·06	16	0·06	245	0·03	303
25. 13 2								
26. 1 21	18·34	4·76	0·06	356	0·09	240	0·07	31
26. 13 42								
27. 2 2	17·56	4·51	0·09	246	0·04	251	0·05	65
27. 14 20								
28. 2 37	18·01	4·29	0·01	260	0·04	211	0·03	322
28. 14 59								
29. 3 20	17·81	3·97	0·08	200	0·04	208	0·06	31
29. 15 40	17·69	3·77	0·04	238	0·06	241	0·03	94
30. 4 4								
30. 16 25	17·85	3·56	0·08	264	0·03	281	0·01	218
July 1. 4 50								
1. 17 25	17·93	3·30	0·07	308	0·05	222	0·01	251
2. 5 48								
2. 18 22	18·00	3·36	0·09	12	0·04	215	0·01	240
3. 6 55								
3. 19 31	18·70	3·58	0·10	6	0·04	263	0·03	349
4. 7 58								
4. 20 25	18·45	3·90	0·12	24	0·05	277	0·03	258
5. 8 58								
5. 21 23	17·58	4·40	0·15	42	0·07	269	0·04	126
6. 9 49								
6. 22 13	18·01	4·61	0·09	60	0·01	53	0·05	208
7. 10 32								
7. 22 52	18·21	5·12	0·08	40	0·04	172	0·02	297
8. 11 14								
8. 23 35	18·00	5·36	0·07	66	0·04	162	0·04	43
9. 11 59								
10. 0 22	18·18	5·54	0·05	101	0·10	212	0·03	271
10. 12 45								
11. 1 7	18·37	5·71	0·11	17	0·06	199	0·06	247
11. 13 31								
12. 1 55	17·93	5·49	0·15	66	0·05	193	0·06	331
12. 14 21								
13. 2 47	18·16	5·22	0·09	34	0·07	175	0·03	317
13. 15 13	17·59	5·06	0·07	182	0·05	236	0·04	57
14. 3 38								
14. 16 7	17·28	4·60	0·06	204	0·03	216	0·02	9
15. 4 35								
15. 17 10	17·69	4·15	0·07	290	0·05	241	0·02	49
16. 5 44								
16. 18 21	17·96	3·88	0·11	337	0·11	230	0·06	56
17. 6 48								
17. 19 29	17·93	3·85	0·11	13	0·02	312	0·03	198
18. 8 13								
18. 20 39	17·74	4·01	0·08	71	0·01	257	0·01	236
19. 9 5								
19. 21 35	17·66	4·30	0·07	333	0·01	41	0·03	11
20. 9 59								
20. 22 23	17·64	4·53	0·07	334	0·01	250	0·04	41
21. 10 42								
21. 23 1	17·58	4·80	0·04	328	0·01	132	0·02	159
22. 11 19								
22. 23 37	17·50	4·90	0·07	328	0·03	123	0·00	31
23. 11 55								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 24. 0 12	17·54	4·91	0·03	11	0·02	163	0·03	136
24. 12 29								
25. 0 46	17·55	4·87	0·03	104	0·05	140	0·01	151
25. 13 2								
26. 1 18	17·57	4·71	0·06	110	0·01	214	0·03	61
26. 13 36								
27. 1 54	17·43	4·56	0·02	157	0·02	318	0·04	314
27. 14 12								
28. 2 31	17·58	4·31	0·08	118	0·02	212	0·02	74
28. 14 49	17·28	4·08	0·09	206	0·08	233	0·05	71
29. 3 9								
29. 15 26	17·39	3·72	0·08	251	0·08	246	0·04	112
30. 3 46								
30. 16 18	17·39	3·40	0·09	261	0·04	251	0·01	111
31. 4 51								
31. 17 22	17·55	3·24	0·11	314	0·02	179	0·03	124
August 1. 6 1								
1. 18 45	17·97	3·26	0·12	9	0·03	211	0·03	147
2. 7 17								
2. 19 58	17·78	3·69	0·12	60	0·08	69	0·02	325
3. 8 37								
3. 21 8	17·98	4·11	0·03	122	0·04	164	0·00	179
4. 9 37								
4. 22 7	18·24	4·81	0·06	6	0·04	158	0·01	117
5. 10 23								
5. 22 39	17·99	5·28	0·09	99	0·02	162	0·07	321
6. 11 0								
6. 23 22	18·18	5·72	0·13	52	0·05	174	0·02	104
7. 11 44								
8. 0 5	17·88	5·98	0·10	68	0·06	152	0·05	319
8. 12 29								
9. 0 52	18·02	6·01	0·15	67	0·07	174	0·05	3
9. 13 14								
10. 1 36	18·03	5·89	0·11	51	0·06	166	0·01	135
10. 14 1								
11. 2 25	17·93	5·46	0·14	92	0·05	196	0·06	9
11. 14 47	17·93	5·20	0·11	221	0·03	237	0·03	28
12. 3 9								
12. 15 40	17·76	4·50	0·16	224	0·03	223	0·02	82
13. 4 8								
13. 16 42	17·50	3·92	0·06	234	0·03	232	0·03	108
14. 5 17								
14. 18 0	17·46	3·45	0·08	277	0·01	99	0·02	41
15. 6 45								
15. 19 22	17·35	3·42	0·05	6	0·03	286	0·03	192
16. 7 59								
16. 20 33	17·81	3·77	0·06	4	0·04	218	0·01	138
17. 9 3								
17. 21 29	17·74	4·02	0·05	347	0·03	164	0·01	43
18. 9 51								
18. 22 12	17·98	4·51	0·07	344	0·06	168	0·05	71
19. 10 31								
19. 22 49	18·12	4·54	0·09	25	0·09	81	0·06	36
20. 11 5								
20. 23 21	17·65	4·90	0·01	141	0·05	202	0·03	341
21. 11 37								
21. 23 52	17·25	4·95	0·04	30	0·06	179	0·04	182
22. 12 6								
23. 0 20	17·73	5·02	0·06	129	0·07	164	0·04	164
.....	....	....	....	....	....	....	....	....

Height of the Water in each individual tide at Ardglass, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_p.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 23 30	18·35	6·30	0·20	87	0·12	175	0·04	211
23. 11 45								
24. 0 0	18·60	6·35	0·17	73	0·12	231	0·09	188
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
26. 1 13	18·20	6·11	0·15	110	0·05	216	0·03	105
26. 13 34								
27. 1 55	17·62	5·76	0·10	96	0·07	146	0·04	28
27. 14 14								
28. 2 33	17·83	5·40	0·10	99	0·06	188	0·02	61
28. 14 54								
29. 3 15	17·76	4·99	0·14	125	0·05	170	0·01	312
29. 15 36	17·59	4·71	0·09	131	0·11	217	0·02	176
30. 4 0								
30. 16 26	17·71	4·38	0·09	173	0·06	196	0·02	195
July 1. 4 51								
1. 17 22	17·77	4·02	0·06	233	0·07	238	0·01	267
2. 5 45								
2. 18 22	17·81	4·06	0·01	42	0·04	240	0·02	224
3. 6 55								
3. 19 33	18·49	4·33	0·07	345	0·10	244	0·02	43
4. 8 0								
4. 20 27	18·22	4·81	0·24	71	0·15	301	0·14	176
5. 9 0								
5. 21 22	17·41	5·60	0·12	77	0·06	222	0·05	146
6. 9 48								
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
7. 22 56	18·23	6·68	0·12	138	0·11	5	0·08	190
8. 11 16								
8. 23 35	17·76	7·08	0·19	90	0·05	47	0·00	208
9. 11 56								
10. 0 17	17·90	7·24	0·18	93	0·09	157	0·09	35
10. 12 41								
11. 1 5	18·29	7·62	0·15	64	0·16	196	0·16	145
11. 13 30								
12. 1 54	17·75	7·30	0·22	100	0·01	106	0·01	270
12. 14 18								
13. 2 43	17·87	6·78	0·15	69	0·08	137	0·05	109
13. 15 11	17·54	6·53	0·16	116	0·04	128	0·05	215
14. 3 36								
14. 16 9	17·24	5·81	0·15	121	0·02	234	0·03	254
15. 4 37								
15. 17 13	17·52	5·10	0·05	138	0·05	246	0·02	81
16. 5 47								
.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....
17. 19 40	17·77	4·88	0·07	336	0·08	250	0·06	179
18. 8 24								
18. 20 52	17·74	5·26	0·07	53	0·04	232	0·06	171
19. 9 18	17·64	5·50	0·08	60	0·04	296	0·06	124
19. 21 47								
20. 10 11	17·60	5·90	0·07	118	0·08	189	0·03	116
20. 22 35								
21. 10 54	17·54	6·18	0·11	89	0·06	187	0·04	254
21. 23 12								
22. 11 29	17·46	6·39	0·11	132	0·06	143	0·01	112
22. 23 46								
23. 12 3								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 24. 0 20	17·48	6·40	0·10	140	0·08	144	0·03	199
24. 12 38								
25. 0 55	17·48	6·34	0·16	99	0·03	174	0·03	26
25. 13 9								
26. 1 24	17·52	6·18	0·15	118	0·05	144	0·07	196
26. 13 41								
27. 1 58	17·40	5·85	0·21	118	0·07	148	0·02	200
27. 14 15								
28. 2 33	17·47	5·48	0·20	117	0·03	123	0·03	157
28. 14 53								
29. 3 13	17·29	5·07	0·16	129	0·09	187	0·06	213
29. 15 33								
30. 3 53	17·35	4·67	0·12	148	0·04	221	0·03	155
30. 16 21								
31. 4 54	17·34	4·15	0·12	156	0·01	257	0·05	170
31. 17 28								
August 1. 6 7	17·38	3·88	0·07	198	0·02	255	0·01	77
1. 18 48								
2. 7 20	17·71	3·98	0·09	351	0·05	234	0·03	143
2. 20 2								
3. 8 41	17·58	4·63	0·09	63	0·03	55	0·02	197
3. 21 8	17·85	5·25	0·13	105	0·04	168	0·05	209
4. 9 32								
4. 21 55	18·03	6·21	0·12	137	0·08	132	0·04	165
5. 10 18								
5. 22 42	17·91	6·99	0·24	99	0·02	140	0·06	146
6. 11 1								
6. 23 20	18·05	7·60	0·26	78	0·03	124	0·09	127
7. 11 42								
8. 0 3	17·83	8·11	0·27	89	0·12	109	0·04	327
8. 12 25								
9. 0 47	17·88	8·12	0·25	95	0·07	138	0·09	79
9. 13 9								
10. 1 32	17·85	7·80	0·20	87	0·07	139	0·08	57
10. 13 56								
11. 2 20	17·81	7·13	0·32	91	0·04	88	0·03	68
11. 14 51								
12. 3 13	17·88	6·64	0·18	133	0·08	173	0·07	73
12. 15 46								
13. 4 14	17·70	5·62	0·14	132	0·06	193	0·10	127
13. 16 51								
14. 5 26	17·42	4·81	0·10	139	0·03	186	0·01	158
14. 18 7								
15. 6 52	17·36	4·22	0·04	172	0·02	313	0·01	253
15. 19 38								
16. 8 15	17·30	4·29	0·06	95	0·02	84	0·02	182
16. 20 46								
17. 9 16	17·71	4·75	0·13	88	0·03	253	0·04	135
17. 21 40	17·66	5·20	0·08	140	0·02	174	0·02	149
18. 10 1								
18. 22 21	17·91	5·80	0·13	76	0·16	211	0·10	99
19. 10 36								
19. 22 51	17·99	6·00	0·24	62	0·05	204	0·03	92
20. 11 5								
20. 23 18	17·57	6·45	0·27	146	0·10	236	0·09	340
21. 11 37								
21. 23 55	17·15	6·53	0·20	117	0·05	166	0·03	27
22. 12 7								
23. 0 19	17·62	6·57	0·14	111	0·06	111	0·05	210
.....	....	....	....	....	....	....	....	....

Height of the Water in each individual tide at Clogher Head, excluding diurnal tide,

Analysed time of high water, corresponding to $p = 90°$.	A_p.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 24. 0 6	17·96	6·22	0·22	126	0·07	161	0·05	200
24. 12 24								
25. 0 42	17·93	6·16	0·25	113	0·06	166	0·03	307
25. 12 59								
26. 1 16	17·48	5·99	0·23	124	0·04	202	0·05	167
26. 13 37								
27. 1 57	17·15	5·58	0·27	116	0·07	145	0·02	162
27. 14 17								
28. 2 36	17·35	5·30	0·16	119	0·05	120	0·04	177
28. 14 57								
29. 3 18	17·29	4·79	0·21	123	0·05	153	0·03	233
29. 15 39								
30. 4 3	17·13	4·50	0·19	137	0·02	85	0·08	178
30. 16 27								
July 1. 4 52	17·26	4·18	0·13	149	0·10	190	0·03	116
1. 17 27								
2. 5 50	17·21	3·83	0·18	178	0·10	281	0·05	156
2. 18 29								
3. 7 2	17·34	3·99	0·08	175	0·08	212	0·03	68
3. 19 32								
4. 7 59	17·88	4·28	0·06	336	0·10	227	0·07	205
4. 20 31								
5. 9 4	17·52	4·90	0·10	141	0·06	52	0·04	126
5. 21 28	17·01	5·28	0·20	117	0·03	184	0·03	207
6. 9 53								
6. 22 17	17·40	6·00	0·21	113	0·11	145	0·10	106
7. 10 37								
7. 22 57	17·61	6·61	0·24	119	0·08	118	0·04	113
8. 11 21								
8. 23 44	17·53	7·11	0·41	111	0·05	101	0·05	325
9. 12 7								
10. 0 29	17·54	7·36	0·34	111	0·05	75	0·02	85
10. 12 54								
11. 1 19	17·95	7·50	0·29	123	0·08	203	0·10	253
11. 13 43								
12. 2 6	17·29	7·27	0·40	124	0·06	202	0·05	274
12. 14 31								
13. 2 55	17·34	6·71	0·25	103	0·04	170	0·08	194
13. 15 15								
14. 3 40	16·72	6·16	0·07	291	0·23	124	0·07	209
14. 16 24								
15. 4 52	16·84	5·68	0·24	133	0·02	185	0·04	254
15. 17 28								
16. 6 2	17·14	5·10	0·14	113	0·09	226	0·03	45
16. 18 32								
17. 7 0	17·10	4·95	0·13	205	0·14	204	0·08	329
17. 19 44								
18. 8 28	17·30	4·60	0·11	288	0·16	159	0·11	336
18. 21 6								
19. 9 32	17·14	5·20	0·11	195	0·07	252	0·07	187
19. 21 59	17·26	5·20	0·11	339	0·13	170	0·10	274
20. 10 23								
20. 22 46	17·15	5·61	0·18	121	0·09	306	0·05	122
21. 11 3								
21. 23 19	17·10	6·04	0·22	125	0·06	146	0·04	291
22. 11 37								
22. 23 54	17·11	6·02	0·19	76	0·25	165	0·14	310
23. 12 13								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 24. 0 32	16·97	6·07	0·04	17	0·28	176	0·08	20
24. 12 51								
25. 1 10	17·24	5·99	0·25	107	0·38	180	0·14	251
25. 13 20								
26. 1 29	16·99	6·05	0·06	143	0·16	143	0·05	276
26. 13 46								
27. 2 2	16·94	5·70	0·36	121	0·16	214	0·05	130
27. 14 20								
28. 2 37	17·11	5·24	0·27	106	0·02	239	0·06	228
28. 15 5	17·02	5·01	0·28	96	0·16	162	0·05	244
29. 3 25								
29. 15 45	16·94	4·60	0·27	150	0·12	77	0·06	261
30. 4 5								
30. 16 41	16·81	3·96	0·18	227	0·12	151	0·10	238
31. 5 14								
31. 17 38	16·99	3·68	0·14	203	0·13	195	0·05	280
August 1. 6 17								
1. 18 59	17·29	3·85	0·06	295	0·07	234	0·03	193
2. 7 31								
2. 20 12	17·38	4·29	0·12	128	0·04	167	0·01	174
3. 8 51								
3. 21 16	17·49	5·23	0·08	125	0·05	186	0·04	133
4. 9 35								
4. 22 17	16·95	6·06	0·52	230	0·15	236	0·08	106
5. 10 33								
5. 22 48	17·44	6·99	0·24	108	0·08	70	0·06	130
6. 11 6								
6. 23 24	17·53	7·78	0·30	102	0·06	72	0·05	135
7. 11 48								
8. 0 12	17·16	8·03	0·31	123	0·07	153	0·10	178
8. 12 35								
9. 0 57	17·18	8·10	0·03	113	0·17	305	0·10	345
9. 13 16								
10. 1 34	17·37	7·76	0·34	109	0·11	85	0·10	113
10. 14 2								
11. 2 30	17·54	6·91	0·63	87	0·19	185	0·10	327
11. 14 48	17·26	6·39	0·32	140	0·24	103	0·09	186
12. 3 10								
12. 15 48	17·27	5·34	0·28	88	0·19	148	0·10	339
13. 4 16								
13. 16 56	17·36	4·64	0·57	103	0·14	227	0·03	41
14. 5 31								
14. 18 6	17·16	3·99	0·35	122	0·14	135	0·05	81
15. 6 51								
15. 19 46	17·11	4·21	0·28	71	0·10	253	0·05	27
16. 8 23								
16. 20 53	17·48	4·66	0·26	112	0·12	350	0·06	11
17. 9 23	17·23	4·97	0·19	142	0·03	177	0·05	266
17. 21 50								
18. 10 11	17·50	5·70	0·18	96	0·04	121	0·12	45
18. 22 32								
19. 10 45	17·70	5·92	0·43	100	0·10	183	0·08	56
19. 22 57								
20. 11 11	16·85	6·20	0·19	324	0·19	178	0·04	245
20. 23 24								
21. 11 42	16·76	6·27	0·22	108	0·26	171	0·07	296
22. 0 0								
22. 12 15	17·16	6·59	0·18	124	0·09	325	0·02	238
23. 0 29	....	....	....	....	....	....	....	....
.....								

Height of the Water in each individual tide at Kingstown, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 23 21	17·99	4·91	0·33	147	0·06	258	0·06	165
23. 11 52								
24. 0 11	18·14	4·70	0·35	149	0·03	39	0·01	31
24. 12 28								
25. 0 45	18·12	4·69	0·31	147	0·02	129	0·05	132
25. 13 3								
26. 1 21	17·72	4·56	0·38	153	0·08	351	0·03	72
26. 13 43								
27. 2 4	17·35	4·19	0·33	146	0·02	253	0·03	197
27. 14 28								
28. 2 40	17·24	4·14	0·26	152	0·05	238	0·02	33
28. 15 0								
29. 3 29	17·42	3·84	0·27	154	0·04	153	0·04	141
29. 15 50								
30. 4 15	17·31	3·48	0·25	83	0·06	144	0·04	8
30. 16 45								
July 1. 5 10	17·48	3·18	0·23	178	0·03	189	0·02	89
1. 17 47								
2. 6 10	17·50	2·95	0·25	177	0·06	202	0·04	200
2. 18 44								
3. 7 17	17·60	3·04	0·17	196	0·02	273	0·00	264
3. 19 51								
4. 8 18	18·18	3·21	0·18	195	0·04	216	0·01	40
4. 20 43								
5. 9 16	17·86	3·65	0·16	182	0·01	148	0·03	184
5. 21 39								
6. 10 5	17·18	4·19	0·25	171	0·02	17	0·01	4
6. 22 20	17·55	4·66	0·31	159	0·06	70	0·04	158
7. 10 39								
7. 22 57	17·87	5·13	0·35	151	0·06	33	0·03	164
8. 11 21								
8. 23 45	17·53	5·61	0·43	147	0·05	304	0·02	115
9. 12 6								
10. 0 27	17·69	5·68	0·50	134	0·06	314	0·04	104
10. 12 54								
11. 1 20	18·04	5·88	0·36	146	0·09	47	0·04	113
11. 13 43								
12. 2 5	17·37	5·52	0·44	138	0·03	340	0·02	342
12. 14 32								
13. 2 58	17·40	5·13	0·33	143	0·05	55	0·03	160
13. 15 31								
14. 3 56	17·19	4·88	0·43	143	0·04	17	0·04	229
14. 16 33								
15. 5 1	17·07	4·35	0·38	155	0·02	334	0·02	289
15. 17 38								
16. 6 12	17·50	3·86	0·30	164	0·02	229	0·02	196
16. 18 51								
17. 7 21	17·70	3·66	0·27	180	0·01	312	0·03	128
17. 19 57								
18. 8 41	17·70	3·63	0·27	175	0·01	337	0·03	190
18. 21 9	17·53	3·76	0·28	174	0·03	122	0·04	151
19. 9 37								
19. 22 5	17·58	4·08	0·28	165	0·05	214	0·05	348
20. 10 25								
20. 22 45	17·34	4·32	0·35	165	0·01	211	0·02	48
21. 11 4								
21. 23 23	17·34	4·59	0·37	152	0·05	269	0·03	140
22. 11 39								
22. 23 54	17·22	4·76	0·34	149	0·02	39	0·02	53
23. 12 10								

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 24. 0 26	17·27	4·74	0·33	145	0·05	85	0·04	159
24. 12 42								
25. 0 58	17·17	4·66	0·36	142	0·06	8	0·05	91
25. 13 14								
26. 1 30	17·27	4·48	0·29	148	0·03	88	0·05	229
26. 13 48								
27. 2 6	17·23	4·28	0·32	141	0·05	257	0·04	23
27. 14 24								
28. 2 42	17·24	3·98	0·25	144	0·03	177	0·02	7
28. 15 3	17·16	3·71	0·18	150	0·03	328	0·03	116
29. 3 23								
29. 15 47	17·17	3·39	0·25	160	0·03	169	0·04	142
30. 4 7								
30. 16 41	17·12	3·01	0·22	160	0·04	279	0·06	141
31. 5 14								
31. 17 48	17·19	2·86	0·27	189	0·01	108	0·02	70
August 1. 6 27								
1. 19 8	17·48	3·08	0·11	214	0·05	214	0·03	65
2. 7 40								
2. 20 23	17·33	3·50	0·15	175	0·04	211	0·02	185
3. 9 2								
3. 21 20	17·52	3·91	0·19	147	0·03	101	0·02	168
4. 9 42								
4. 22 3	17·75	4·73	0·34	141	0·03	168	0·00	187
5. 10 26								
5. 22 48	17·59	5·39	0·34	148	0·04	40	0·01	174
6. 11 8								
6. 23 28	17·70	5·91	0·44	135	0·07	14	0·10	133
7. 11 47								
8. 0 6	17·38	6·39	0·49	130	0·07	336	0·07	90
8. 12 29								
9. 0 51	17·62	6·31	0·50	124	0·01	309	0·08	108
9. 13 15								
10. 1 40	17·61	6·05	0·33	141	0·07	6	0·05	47
10. 14 3								
11. 2 26	17·50	5·47	0·46	133	0·02	320	0·05	179
11. 15 7	17·56	4·91	0·46	154	0·08	22	0·10	212
12. 3 29								
12. 15 55	17·36	4·17	0·21	141	0·09	230	0·06	128
13. 4 23								
13. 17 8	17·17	3·58	0·26	168	0·02	343	0·02	152
14. 5 43								
14. 18 28	17·22	3·24	0·19	178	0·05	274	0·04	182
15. 7 13								
15. 19 54	17·13	3·25	0·19	185	0·02	215	0·02	157
16. 8 31								
16. 20 57	17·63	3·58	0·20	157	0·04	217	0·01	127
17. 9 27								
17. 21 55	17·49	3·69	0·27	193	0·09	255	0·01	46
18. 10 12								
18. 22 28	17·67	4·30	0·25	165	0·00	357	0·01	8
19. 10 41								
19. 22 53	17·64	4·49	0·34	157	0·05	24	0·04	210
20. 11 9								
20. 23 25	17·37	4·81	0·34	144	0·01	269	0·01	314
21. 11 44								
22. 0 3	16·84	4·94	0·28	147	0·05	308	0·06	103
22. 12 15								
23. 0 26	17·42	4·92	0·31	143	0·05	57	0·03	104
....	....	....	....	....	....	....	....	....

Height of the Water in each individual tide at Dunmore East, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 17 37	16·29	5·30	0·23	16	0·07	82	0·04	239
23. 5 55								
23. 18 21	16·38	5·32	0·07	346	0·15	115	0·06	232
24. 6 45								
24. 18 53	16·23	5·12	0·13	321	0·14	126	0·03	263
25. 7 12	16·37	5·07	0·06	306	0·17	146	0·08	166
25. 19 31	16·25	5·16	0·11	327	0·12	89	0·03	314
26. 7 47	16·02	4·98	0·13	2	0·14	99	0·06	215
26. 20 5	15·71	4·98	0·10	340	0·17	107	0·01	158
27. 8 22	15·75	4·88	0·14	5	0·14	75	0·06	273
27. 20 36	15·69	4·62	0·07	49	0·18	97	0·05	250
28. 8 52	15·73	4·43	0·07	11	0·20	74	0·03	206
28. 21 17	15·84	4·28	0·06	17	0·17	89	0·02	320
29. 9 33	15·74	4·07	0·07	322	0·18	95	0·06	250
29. 21 50	15·88	3·98	0·08	9	0·14	80	0·02	207
30. 10 14	15·90	3·80	0·09	356	0·13	102	0·07	165
30. 22 24	15·84	3·56	0·10	341	0·07	113	0·03	267
July 1. 10 57	15·85	3·40	0·09	347	0·08	134	0·03	67
1. 23 22	15·81	3·19	0·12	345	0·08	129	0·01	142
2. 11 51	15·76	3·13	0·04	336	0·08	142	0·03	259
3. 0 39	16·28	3·08	0·18	13	0·08	115	0·02	131
3. 13 17								
4. 1 54	16·63	3·50	0·10	28	0·09	153	0·03	213
4. 14 26								
5. 2 57	16·04	3·93	0·07	67	0·02	190	0·04	194
5. 15 20								
6. 3 43	15·58	4·52	0·09	360	0·09	114	0·03	244
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
7. 17 3	16·06	5·38	0·15	44	0·16	129	0·04	25
8. 5 21								
8. 17 49	15·93	5·81	0·20	3	0·15	106	0·02	268
9. 6 9								
9. 18 30	16·00	6·21	0·12	15	0·18	90	0·02	224
10. 6 54								
10. 19 12	16·41	6·21	0·26	10	0·18	105	0·06	208
11. 7 36								
11. 20 2	15·73	6·00	0·15	16	0·22	97	0·01	32
12. 8 25								
12. 20 48	15·64	5·69	0·12	15	0·24	105	0·05	242
13. 9 12								
13. 21 36	15·36	5·08	0·17	339	0·14	114	0·02	134
14. 10 4								
14. 22 31	15·51	4·52	0·18	6	0·14	114	0·05	294
15. 10 56								
15. 23 22	16·02	3·92	0·21	2	0·12	115	0·04	338
16. 11 58								
17. 0 34	16·20	3·55	0·19	3	0·07	136	0·03	262
17. 13 15								
18. 1 55	16·11	3·62	0·10	48	0·12	151	0·03	141
18. 14 29								
19. 3 3	16·05	4·10	0·08	36	0·08	88	0·01	49
19. 15 33								
20. 4 0	16·05	4·45	0·15	15	0·09	127	0·01	119
20. 16 25								
21. 4 43	15·78	4·80	0·21	6	0·11	118	0·03	165
21. 17 15								
22. 5 31	15·83	5·13	0·19	27	0·12	109	0·03	97
22. 17 53								
23. 6 10	15·73	5·31	0·15	39	0·17	91	0·02	272

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 22	15·72	5·39	0·18	13	0·14	96	0·08	141
24. 6 38								
24. 18 55	15·82	5·35	0·13	17	0·19	76	0·05	244
25. 7 15								
25. 19 30	15·77	5·21	0·19	31	0·21	47	0·08	316
26. 7 47								
26. 20 2	15·65	4·90	0·12	339	0·15	95	0·05	284
27. 8 18								
27. 20 33	15·57	4·62	0·14	8	0·18	91	0·03	213
28. 8 49								
28. 21 5	15·54	4·22	0·20	322	0·21	93	0·02	254
29. 9 22								
29. 21 39	15·66	3·86	0·10	352	0·13	84	0·05	191
30. 10 4								
30. 22 28	15·51	3·33	0·18	328	0·09	116	0·04	96
31. 11 2								
31. 23 36	15·64	2·92	0·11	3	0·01	125	0·02	285
August 1. 12 22								
2. 1 7	15·89	2·90	0·13	7	0·05	196	0·03	147
2. 13 50								
3. 2 33	15·72	3·55	0·08	107	0·04	143	0·06	269
3. 15 7								
4. 3 39	15·69	4·29	0·08	50	0·11	109	0·04	52
4. 16 13								
5. 4 33	15·87	5·00	0·12	23	0·20	105	0·08	347
5. 16 57								
6. 5 21	15·91	5·90	0·17	10	0·12	95	0·08	176
6. 17 49								
7. 6 9	15·93	6·40	0·14	22	0·16	100	0·01	133
7. 18 34								
8. 6 57	15·86	6·60	0·10	343	0·20	68	0·10	40
8. 19 20								
9. 7 41	15·99	6·68	0·09	6	0·23	80	0·11	5
9. 20 4	16·00	6·51	0·10	346	0·21	108	0·01	37
10. 8 24								
10. 20 44	15·68	5·92	0·14	358	0·27	107	0·04	29
11. 9 4								
11. 21 24	15·72	5·33	0·22	5	0·22	93	0·02	140
12. 9 47								
12. 22 10	15·53	4·46	0·02	6	0·23	101	0·02	322
13. 10 37								
13. 23 3	15·39	3·64	0·18	329	0·13	128	0·01	50
14. 11 42								
15. 0 21	15·56	3·06	0·14	10	0·08	137	0·01	84
15. 13 6								
16. 1 51	15·57	3·23	0·09	14	0·07	167	0·02	131
16. 14 30								
17. 3 9	16·00	3·80	0·10	17	0·08	108	0·03	158
17. 15 30								
18. 4 0	16·03	4·31	0·22	0	0·12	127	0·05	120
18. 16 22								
19. 4 43	16·15	4·85	0·06	71	0·23	57	0·10	235
19. 17 5								
20. 5 19	15·94	5·03	0·10	353	0·12	120	0·04	219
20. 17 40								
21. 5 56	15·77	5·38	0·08	347	0·15	95	0·07	203
21. 18 16								
22. 6 28	15·46	5·60	0·14	356	0·18	84	0·03	257
22. 18 41								
23. 6 59	16·00	5·59	0·06	26	0·23	80	0·03	326

Height of the Water in each individual tide at New Ross, excluding diurnal tide.

Analysed time of high water, corresponding to $p=90°$.	A_p.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 18 14	17·32	5·88	0·05	350	0·31	93	0·01	259
23. 6 36								
23. 18 55	17·47	5·85	0·40	350	0·34	92	0·17	140
24. 7 23								
24. 19 44	17·47	5·65	0·29	340	0·40	108	0·04	107
25. 7 54								
25. 20 13	16·80	5·61	0·61	342	0·22	100	0·05	104
26. 8 27								
26. 20 51	16·57	5·43	0·43	334	0·32	101	0·02	58
27. 9 6								
27. 21 21	16·61	5·18	0·37	334	0·27	91	0·01	322
28. 9 38								
28. 21 54	16·57	4·83	0·32	329	0·23	87	0·03	300
29. 10 14								
29. 22 33	16·53	4·50	0·37	343	0·25	89	0·11	114
30. 10 52								
30. 23 10	16·55	4·25	0·27	328	0·15	85	0·03	10
July 1. 11 39								
2. 0 7	16·50	3·75	0·30	331	0·17	89	0·02	69
2. 12 42								
3. 1 18	16·96	3·69	0·26	354	0·19	91	0·01	222
3. 13 54								
4. 2 29	17·56	3·96	0·13	327	0·13	104	0·05	25
4. 14 54								
5. 3 35	17·19	4·34	0·25	350	0·17	99	0·03	158
5. 16 14								
6. 4 45	16·30	5·00	0·33	355	0·23	107	0·05	137
6. 17 14								
7. 5 41	16·94	5·48	0·44	355	0·28	99	0·07	109
7. 18 3								
8. 6 21	17·11	5·88	0·51	341	0·39	97	0·03	106
8. 18 58								
9. 7 18	16·86	6·22	0·52	339	0·36	109	0·04	116
9. 19 49								
10. 8 8	17·03	6·43	0·53	346	0·38	104	0·07	131
10. 20 28								
11. 8 54	17·74	6·39	0·51	343	0·37	93	0·06	108
11. 21 19								
12. 9 43	17·04	6·34	0·66	344	0·35	99	0·06	56
12. 22 7								
13. 10 29	16·97	6·13	0·56	348	0·38	92	0·09	97
13. 22 48								
14. 11 12	16·39	5·67	0·49	341	0·30	95	0·03	104
14. 23 36								
15. 12 2	16·23	5·18	0·46	336	0·24	100	0·02	63
16. 0 27								
16. 12 55	16·81	4·67	0·39	343	0·26	96	0·01	327
17. 1 23								
17. 14 6	16·98	4·24	0·31	342	0·21	123	0·02	312
18. 2 49								
18. 15 27	16·92	4·25	0·30	358	0·18	103	0·01	246
19. 4 0								
19. 16 37	16·79	4·61	0·42	347	0·16	100	0·00	270
20. 5 4								
20. 17 33	16·79	5·08	0·40	352	0·21	104	0·02	352
21. 5 51								
21. 18 14	16·64	5·42	0·46	347	0·25	101	0·01	116
22. 6 30								
22. 18 53	16·69	5·75	0·52	347	0·29	91	0·03	68
23. 7 10								
	16·64	5·87	0·50	351	0·34	101	0·06	116

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 19 27	16·59	5·93	0·51	351	0·31	93	0·10	109
24. 7 43								
24. 19 58	16·59	5·92	0·54	351	0·35	89	0·07	98
25. 8 18								
25. 20 31	16·59	5·80	0·47	343	0·34	91	0·04	47
26. 8 46								
26. 21 0	16·48	5·52	0·39	347	0·31	95	0·06	134
27. 9 15								
27. 21 31	16·36	5·25	0·40	346	0·25	92	0·01	339
28. 9 45								
28. 21 58	16·20	4·87	0·27	337	0·29	87	0·02	276
29. 10 15								
29. 22 32	16·24	4·49	0·39	328	0·23	65	0·03	23
30. 10 51								
30. 23 10	16·16	3·95	0·29	321	0·18	82	0·02	55
31. 11 41								
August 1. 0 12	16·35	3·58	0·32	329	0·13	90	0·01	242
1. 12 54								
2. 1 36	16·66	3·47	0·27	14	0·15	104	0·06	159
2. 14 23								
3. 3 10	16·40	4·17	0·20	6	0·13	94	0·05	227
3. 15 42								
4. 4 21	16·50	4·90	0·30	352	0·21	97	0·02	70
4. 16 54								
5. 5 14	16·82	5·61	0·43	341	0·35	85	0·02	314
5. 17 57								
6. 6 21	16·78	6·30	0·59	348	0·35	101	0·07	101
6. 18 47								
7. 7 7	17·05	6·76	0·58	351	0·39	100	0·07	90
7. 19 34								
8. 7 57	17·15	6·89	0·59	353	0·41	91	0·05	79
8. 20 27	17·13	6·95	0·68	348	0·42	98	0·12	92
9. 8 43								
9. 20 59	17·14	6·81	0·63	349	0·49	93	0·16	113
10. 9 21								
10. 21 42	16·77	6·31	0·59	342	0·39	106	0·09	85
11. 9 58								
11. 22 15	16·88	5·86	0·49	340	0·39	101	0·06	132
12. 10 36								
12. 22 57	16·33	5·09	0·41	336	0·26	99	0·03	66
13. 11 22								
13. 23 46	16·10	4·26	0·37	323	0·17	103	0·05	34
14. 12 22								
15. 0 58	16·26	3·70	0·25	343	0·17	105	0·05	301
15. 13 44								
16. 2 30	16·28	3·82	0·24	347	0·14	100	0·01	122
16. 15 14								
17. 3 44	16·52	4·20	0·27	343	0·13	122	0·04	43
17. 16 15								
18. 4 47	16·63	4·91	0·35	358	0·23	80	0·09	141
18. 17 11								
19. 5 32	16·87	5·39	0·38	348	0·28	95	0·05	164
19. 17 57								
20. 6 11	16·83	5·52	0·39	339	0·26	108	0·04	185
20. 18 35								
21. 6 51	16·59	5·06	0·56	347	0·35	93	0·08	69
21. 19 12								
22. 7 24	16·18	6·03	0·50	344	0·39	97	0·08	110
22. 19 33								
23. 7 51	16·84	6·09	0·48	352	0·34	92	0·01	144

Height of the Water in each individual tide at Passage West, excluding diurnal tide,

Analysed time of high water, corresponding to $\mu = 90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
June 24. 19 6 / 25. 7 16	16·13	5·37	0·36	279	0·06	104	0·03	92
.....	.....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
26. 20 6 / 27. 8 25	15·52	5·02	0·31	290	0·12	80	0·03	68
27. 20 43 / 28. 9 3	15·55	4·64	0·32	289	0·11	60	0·03	122
28. 21 23 / 29. 9 40	15·53	4·30	0·31	295	0·16	70	0·01	58
29. 22 4 / 30. 10 34	15·62	3·91	0·33	305	0·06	67	0·02	94
30. 23 20	15·69	3·73	0·23	301	0·07	116	0·01	6
July 1. 11 33								
1. 23 46	15·64	3·46	0·26	316	0·10	97	0·03	129
2. 12 23								
3. 0 59	16·11	3·38	0·25	358	0·08	158	0·08	298
3. 13 32								
4. 2 4	16·40	3·73	0·20	331	0·03	157	0·03	109
4. 14 34								
5. 3 4	15·73	4·20	0·14	312	0·03	123	0·03	83
5. 15 36 / 6. 4 6	15·34	4·65	0·19	300	0·07	101	0·03	74
6. 16 32 / 7. 4 59	15·92	5·11	0·21	331	0·07	102	0·07	69
7. 17 22 / 8. 5 40	15·76	5·70	0·28	310	0·09	92	0·01	88
8. 18 8 / 9. 6 28	15·63	6·03	0·36	299	0·10	131	0·05	31
9. 18 52 / 10. 7 16	16·01	6·25	0·25	284	0·13	38	0·02	353
10. 19 36 / 11. 8 0	16·38	6·38	0·27	308	0·06	102	0·09	103
11. 20 28 / 12. 8 51	15·72	6·21	0·32	307	0·12	98	0·07	89
12. 21 15	15·52	5·96	0·36	309	0·20	80	0·10	64
13. 9 39								
13. 22 3	15·32	5·36	0·30	309	0·17	84	0·06	64
14. 10 31								
14. 22 58	15·39	4·86	0·36	313	0·14	99	0·04	106
15. 11 28								
15. 23 58	16·05	4·31	0·34	327	0·11	108	0·02	75
16. 12 32								
17. 1 6	16·13	3·91	0·28	307	0·06	118	0·04	71
17. 13 45								
18. 2 23	16·09	3·99	0·22	331	0·05	130	0·01	38
18. 14 57								
19. 3 31	15·96	4·41	0·26	315	0·10	75	0·04	132
19. 15 59 / 20. 4 26	16·01	4·69	0·31	332	0·06	105	0·03	52
20. 16 51 / 21. 5 9	15·71	5·08	0·38	315	0·10	101	0·02	71
21. 17 31 / 22. 5 47	15·79	5·38	0·35	307	0·07	102	0·05	91
22. 18 6 / 23. 6 23	15·68	5·33	0·33	301	0·09	72	0·01	36

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 39	15·73	5·61	0·33	291	0·07	60	0·04	173
24. 6 55								
24. 19 7	15·75	5·58	0·30	293	0·14	48	0·07	94
25. 7 27								
25. 19 39	15·66	5·34	0·28	288	0·08	67	0·08	103
26. 7 56								
26. 20 12	15·60	5·08	0·34	287	0·13	82	0·02	238
27. 8 28								
27. 20 44	15·41	4·73	0·29	291	0·12	65	0·04	79
28. 8 59								
28. 21 18	15·34	4·48	0·26	291	0·17	51	0·04	58
29. 9 37								
29. 21 55	15·57	3·98	0·28	303	0·14	73	0·00	28
30. 10 21								
30. 22 46	15·45	3·53	0·29	302	0·08	104	0·02	325
31. 11 19								
31. 23 51	15·65	3·25	0·25	329	0·07	108	0·03	343
August 1. 12 33								
2. 1 15	15·86	3·30	0·14	357	0·07	173	0·00	262
2. 13 58								
3. 2 40	15·65	3·91	0·12	312	0·04	55	0·01	213
3. 15 8								
4. 3 40	15·52	4·59	0·23	316	0·10	150	0·03	70
4. 16 13								
5. 4 33	15·67	5·29	0·29	316	0·10	135	0·03	91
5. 17 1								
6. 5 25	15·79	6·12	0·25	298	0·06	111	0·08	86
6. 17 50								
7. 6 10	15·79	6·62	0·21	299	0·09	106	0·09	88
7. 18 34								
8. 6 57	15·78	6·89	0·30	294	0·08	110	0·06	37
8. 19 19								
9. 7 40	15·95	6·93	0·30	275	0·04	140	0·09	34
9. 20 2								
10. 8 26	15·89	6·63	0·29	289	0·11	75	0·04	38
10. 20 46	15·64	6·20	0·36	297	0·15	79	0·06	46
11. 9 7								
11. 21 28	15·68	5·60	0·28	298	0·17	77	0·11	100
12. 9 54								
12. 22 20	15·43	4·72	0·35	312	0·15	83	0·04	131
13. 10 51								
13. 23 21	15·31	3·90	0·37	314	0·11	91	0·02	25
14. 12 1								
15. 0 40	15·46	3·50	0·26	343	0·10	134	0·07	30
15. 13 23								
16. 2 6	15·58	3·60	0·19	329	0·05	158	0·05	24
16. 14 40								
17. 3 13	15·84	4·14	0·22	317	0·05	90	0·03	33
17. 15 44								
18. 4 14	15·99	4·47	0·23	339	0·08	50	0·06	152
18. 16 27								
19. 4 48	16·01	5·02	0·25	312	0·11	73	0·04	99
19. 17 10								
20. 5 24	15·80	5·30	0·34	311	0·08	96	0·09	69
20. 17 40								
21. 5 56	15·65	5·60	0·27	296	0·05	44	0·08	73
21. 18 14								
22. 6 26	15·31	5·80	0·33	291	0·07	64	0·08	51
22. 18 40								
23. 6 58	15·83	5·78	0·28	295	0·10	63	0·09	54

Height of the Water in each individual tide at Castle Townsend, excluding diurnal tide,

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
June 22. 17 1	15·86	4·31	0·15	283	0·07	208	0·02	170
23. 5 20								
23. 17 45	15·77	4·49	0·17	276	0·02	77	0·05	277
24. 6 10								
24. 18 36	15·72	4·21	0·27	266	0·07	259	0·03	13
25. 6 46								
25. 19 7	15·41	4·15	0·21	271	0·03	239	0·03	203
26. 7 21								
26. 19 41	15·21	3·98	0·23	292	0·02	18	0·02	3
27. 8 0								
27. 20 20	15·20	3·65	0·17	277	0·04	243	0·01	309
28. 8 40								
28. 21 0	15·30	3·37	0·16	315	0·06	51	0·13	63
29. 9 17								
29. 21 40	15·43	3·11	0·16	306	0·04	269	0·02	182
30. 10 10								
30. 22 39	15·29	2·83	0·19	317	0·05	315	0·02	147
July 1. 11 8								
1. 23 37	15·44	2·70	0·16	323	0·01	221	0·02	266
2. 12 6								
3. 0 35	15·92	2·80	0·04	259	0·09	263	0·04	338
3. 13 12								
4. 1 48	16·04	3·01	0·15	345	0·14	295	0·02	35
4. 14 15								
5. 2 42	15·42	3·37	0·17	299	0·07	328	0·04	190
5. 15 12								
6. 3 41	15·16	3·85	0·12	312	0·08	259	0·09	31
6. 16 2								
7. 4 24	15·42	4·34	0·17	276	0·06	344	0·01	61
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
8. 17 35	15·27	5·06	0·19	296	0·06	265	0·06	294
9. 5 55								
9. 18 10	15·34	5·06	0·37	325	0·17	203	0·07	34
10. 6 34								
10. 18 59	15·92	5·28	0·18	280	0·04	313	0·06	309
11. 7 23								
11. 19 50	15·35	5·11	0·27	296	0·04	274	0·04	106
12. 8 13								
12. 20 42	15·12	4·77	0·24	269	0·05	264	0·09	256
13. 9 6								
13. 21 32	14·85	4·32	0·26	287	0·06	222	0·10	30
14. 9 59								
.....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....
15. 23 29	15·77	3·47	0·17	262	0·11	285	0·07	16
16. 12 6								
17. 0 43	15·65	3·55	0·18	1	0·13	77	0·13	108
17. 13 22								
18. 2 0	15·72	3·31	0·18	295	0·06	284	0·04	154
18. 14 33								
19. 3 5	15·66	3·61	0·19	307	0·03	323	0·05	202
19. 15 32								
20. 3 59	15·66	3·92	0·27	316	0·07	329	0·01	337
20. 16 26								
21. 4 44	15·47	4·16	0·25	318	0·04	52	0·04	137
21. 17 2								
22. 5 18	15·59	4·31	0·17	303	0·08	237	0·03	243
22. 17 35								
23. 5 52	15·41	4·40	0·23	281	0·05	116	0·01	184

expressed by the formula $A_0+C_1\sin p+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$.

Analysed time of high water, corresponding to $p=90°$.	A_0.	C_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	ft.	°	ft.	°	ft.	°
July 23. 18 5	15·45	4·43	0·15	279	0·13	125	0·06	67
24. 6 21								
24. 18 36	15·43	4·43	0·31	281	0·06	179	0·05	351
25. 6 56								
25. 19 14	15·39	4·27	0·18	293	0·08	307	0·03	281
26. 7 31								
26. 19 46	15·38	4·04	0·23	293	0·04	233	0·08	7
27. 8 2								
27. 20 19	15·20	3·71	0·23	282	0·11	271	0·03	78
28. 8 34								
28. 20 57	15·36	3·42	0·33	295	0·07	227	0·14	122
29. 9 16								
29. 21 40	15·31	3·02	0·19	274	0·05	281	0·04	79
30. 10 5								
30. 22 39	15·29	2·71	0·20	318	0·01	90	0·07	118
31. 11 13								
31. 23 46	15·41	2·58	0·15	322	0·01	224	0·01	247
August 1. 12 27								
2. 1 7	15·61	2·70	0·07	354	0·06	311	0·02	359
2. 13 44								
3. 2 20	15·43	3·20	0·08	332	0·01	110	0·02	221
3. 14 50								
4. 3 20	15·34	3·87	0·03	295	0·03	146	0·06	52
4. 15 45								
5. 4 9	15·40	4·49	0·15	333	0·10	285	0·04	108
5. 16 41	15·52	5·07	0·16	263	0·09	57	0·09	300
6. 5 5								
6. 17 33	15·51	5·44	0·25	32	0·06	328	0·03	100
7. 5 53								
7. 17 56	15·47	5·70	0·24	299	0·19	231	0·12	349
8. 6 19								
8. 18 37	15·65	5·80	0·30	282	0·07	323	0·04	300
9. 6 58								
9. 19 26	15·59	5·41	0·29	277	0·07	163	0·01	315
10. 7 50								
10. 20 13	15·49	4·90	0·25	318	0·14	284	0·07	295
11. 8 39								
11. 21 9	15·33	4·34	0·20	301	0·09	326	0·03	348
12. 9 32								
12. 21 58	15·22	3·60	0·21	294	0·06	283	0·02	216
13. 10 31								
13. 23 7	15·19	3·18	0·26	323	0·03	24	0·02	96
14. 11 50								
15. 0 33	15·23	2·85	0·20	312	0·08	333	0·07	41
15. 13 13								
16. 1 53	15·33	2·90	0·12	317	0·03	230	0·05	18
16. 14 28								
17. 3 2	15·58	3·30	0·16	307	0·04	321	0·00	329
17. 15 27								
18. 3 52	15·74	3·72	0·17	311	0·03	3	0·10	74
18. 16 10								
19. 4 28	15·61	4·04	0·18	298	0·09	259	0·04	55
19. 16 49	15·58	4·28	0·27	306	0·05	276	0·07	268
20. 5 3								
20. 17 21	15·43	4·42	0·29	279	0·06	217	0·06	146
21. 5 37								
21. 17 50	15·19	4·67	0·23	299	0·04	28	0·05	149
22. 6 2								
22. 18 13	15·48	4·61	0·27	283	0·04	20	0·05	330
23. 6 31								

Section XI.—*Discussion of the height of mean water deduced from the analysis of individual tides; with reference to difference of station, and to variations of the phase of the moon, and of the declination of the moon.*

The mean heights (A_0) for each station, in the results of last section, were divided into groups corresponding to large tides and small tides, the dividing places being the same as those in section V., page 29, or following by two days the times when the moon's hour-angle from the sun was 3^h, 9^h, 15^h, 21^h. The means for each group were taken, and then the mean of those means of groups belonging to large tides, and the similar mean for small tides. The results are the following, the numbers for Courtown being taken by anticipation from section XVII.:—

Station.	Mean height.		Mean of mean heights.	Excess of mean height in large tides above mean height in small tides.
	Small tides.	Large tides.		
	ft.	ft.	ft.	ft.
Kilbaha	15·58	15·72	15·65	0·14
Kilrush	16·36	16·52	16·44	0·16
Foynes Island....	17·06	17·29	17·18	0·23
Limerick.....	17·38	17·92	17·65	0·54
Casleh Bay.....	17·90	18·06	17·98	0·16
Galway	17·47	17·65	17·56	0·18
Old Head	17·69	17·90	17·80	0·21
Mullaghmore	18·03	18·23	18·13	0·20
Buncrana	17·33	17·47	17·40	0·14
Port Rush	17·60	17·83	17·72	0·23
Carrowkeel.....	17·96	18·17	18·07	0·21
Ballycastle	17·40	17·63	17·52	0·23
Glenarm	17·65	17·83	17·74	0·18
Donaghadee	17·76	17·89	17·83	0·13
Ardglass	17·65	17·78	17·72	0·13
Clogher Head....	17·20	17·32	17·26	0·12
Kingstown	17·44	17·49	17·47	0·05
Courtown	16·63	16·67	16·65	0·04
Dunmore East ..	15·80	15·86	15·83	0·06
New Ross	16·58	16·89	16·74	0·31
Passage West....	15·71	15·78	15·75	0·07
Castle Townsend.	15·45	15·45	15·45	0·00

The first column which deserves attention is the "mean of mean heights." The progress of the numbers from Kilbaha to Limerick, as well as that from Dunmore East to New Ross, show well the change of mean height in ascending a river affected by current as well as by tide. Excluding these river stations, as also Buncrana and Carrowkeel, which partake in some measure of the same character, we have a view of the comparative mean heights of the sea on different parts of the coast of Ireland. And here we have the remarkable result, to which allusion has already been made, that the mean height of the sea round the northern half of the island, as referred to the surface of stagnant water, is considerably greater than that round the southern half of the island. The amount of this difference of height is believed by the officers who directed the levelling operations to be much greater than can be explained by any allowable error in the levelling. The heights on the eastern coast are also, perhaps, a little greater than those on the western coast. I profess myself entirely unable to explain on mechanical principles this result.

In every instance except that of Castle Townsend, the mean height in large tides is greater than that in small tides. Further allusion will be made to this in the examination of the next table. I shall here only remark that I imagine this to be a possible result of the shallowness of the sea, though theory has not yet reached so far.

For the investigation of the effect of the moon's declination, the same process in all respects was used as in Section V., pages 32 and 33, and the following are the results:—

Station.	Mean height with small declination.	Mean height with large declination.	Excess of mean height with large declination above mean height with small declination.	Mean height with decreasing declination.	Mean height with increasing declination.	Excess of mean height with decreasing declination above mean height with increasing declination.
	ft.	ft.	ft.	ft.	ft.	ft.
Kilbaha	15·61	15·66	+0·05	15·68	15·59	+0·09
Kilrush	16·40	16·46	+0·06	16·52	16·34	+0·18
Foynes Island....	17·15	17·18	+0·03	17·24	17·07	+0·17
Limerick.....	17·68	17·57	−0·11	17·81	17·43	+0·38
Casleh Bay.....	17·94	18·00	+0·06	18·03	17·91	+0·12
Galway	17·54	17·58	+0·04	17·62	17·49	+0·13
Old Head	17·71	17·81	+0·10	17·91	17·69	+0·22
Mullaghmore....	18·07	18·15	+0·08	18·22	18·06	+0·16
Buncrana	17·37	17·42	+0·05	17·53	17·31	+0·22
Port Rush	17·68	17·70	+0·02	17·88	17·59	+0·29
Carrowkeel.....	17·97	18·12	+0·15	18·18	17·94	+0·24
Ballycastle.....	17·47	17·59	+0·12	17·64	17·39	+0·25
Glenarm.....	17·68	17·76	+0·08	17·87	17·66	+0·21
Donaghadee	17·79	17·85	+0·06	17·93	17·77	+0·16
Ardglass.....	17·69	17·73	+0·04	17·82	17·64	+0·18
Clogher Head ..	17·21	17·29	+0·08	17·29	17·20	+0·09
Kingstown	17·41	17·50	+0·09	17·53	17·42	+0·11
Courtown	16·60	16·67	+0·07	16·70	16·63	+0·07
Dunmore East ..	15·80	15·88	+0·08	15·90	15·79	+0·11
New Ross	16·74	16·68	−0·06	16·85	16·61	+0·24
Passage West....	15·70	15·77	+0·07	15·77	15·70	+0·07
Castle Townsend..	15·42	15·47	+0·05	15·46	15·44	+0·02

Upon comparing the results of this Table with those of the Table on page 96, the remarks made in page 33 must, I think, be considered to be insufficiently founded. The excess found by classifying according to the magnitude of the tide is here decidedly greater than that found by classifying according to the moon's declination. In the river tides (from Kilbaha to Limerick, and from Dunmore East to New Ross) the excess classified by the magnitude of tide proceeds more regularly than that classified by moon's declination. I think also that the change for the stations on the narrow channel from Port Rush to Donaghadee inclines us to the supposition that the whole is due rather to the variation of magnitude than to the variation of declination. The change of declination, being very slow, would probably produce the same sensible change in the mean level of the deep (though contracted) *sea* of the North Channel as in that of the Atlantic Ocean: though everything which depended in any way upon the tides might be very different. Perhaps however the change for these stations is not sufficiently decided to give great force to this argument. On the whole, I regard the origin of this inequality as yet subject to some doubt.

The values of A_0 at any one station differ, sometimes rapidly, from day to day. In order to examine these, I have subtracted from every value of A_0 at each place the

mean of all the values of A_0 at that place, and have set down the excess as an irregularity in the general height of the water at that place on that day. The numbers for Courtown are taken by anticipation from Section XVII. The results are contained in the following Table. With the view of ascertaining any possible connexion of these irregularities with the cause of the winds, I have set down in the last columns the character of the winds observed at the four stations Kilbaha, Port Rush, Kingstown, and Passage West, which may be considered as nearly equidistant on the coast. [The letter *c* attached to the letters describing the direction of the wind denotes that it was nearly calm; the letter *s* denotes that the wind was strong.]

Approximate time of high water at Kilrush.		Excess of each value of A_0 above the mean value of A_0 at every station.																					Wind.			
		Kilrush.	Foynes Island.	Limerick.	Casleh Bay.	Galway.	Old Head.	Mullaghmore.	Buncrana.	Port Rush.	Carrowkeel.	Ballycastle.	Glenarm.	Donaghadee.	Ardglass.	Clogher Head.	Kingstown.	Courtown.	Dunmore East.	New Ross.	Passage West.	Castle Townsend.	Kilrush.	Port R.	Kingstown.	Passage West.
	hrs.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.				
June 22.	18						+0·71	+0·31	−0·17	+0·19	+0·03			+0·39	+0·63	ft.	+0·52	+0·30	+0·46	+0·58	ft.	+0·41		S.S.W.		
23.	6																							S.W.	W.	
23.	18		+0·70										+0·90	+0·67	+0·88	+0·23	+0·67	+0·67						S.W.S.	S.	
24.	7				+0·59		+0·75	+0·72	+0·98	+0·90	+0·62								+0·55	+0·73		+0·32		S.W.S.		
24.	18	+0·75	+0·76										+0·89	+0·95		+0·67	+0·65	+0·95	+0·40							W.
25.	9				+0·77	+1·03	+0·69	+0·99	+0·82	+0·92	+0·51								+0·54	+0·73	+0·38	+0·27	S.W.S.	S.W.S.		S.W.
25.	19	+0·14	+0·18	+0·39	+0·76	+0·16	+0·28	+0·08	+0·16	+0·53	+0·54	+0·19							+0·42					NW.S.	W.	W.
26.	8												+0·41	+0·51	+0·48	+0·22	+0·25	+0·40	+0·19	+0·06			N.W.	N.W.	W.S.	W.
26.	20	−0·15	−0·15	−0·13	−0·11	−0·13	−0·12	−0·27	−0·12	+0·04	−0·06	−0·25	−0·26	−0·27	−0·10	−0·11	−0·12	−0·08	−0·12	−0·17	−0·23	−0·24	N.W.	N.W.	W.S.	W.N.W.
27.	8																		−0·08				N.W.	N.W.	W.S.	W.
27.	21	0·00	−0·04	+0·03	+0·06	+0·10	+0·18		+0·07	+0·26	+0·20	−0·17	−0·07	+0·13	+0·18	+0·11	+0·09	−0·23	−0·14	−0·13	−0·20	−0·25	S.W.	N.W.	S.C.	W.
28.	9																	−0·05	−0·10				S.W.	W.	N.W.C.	S.W.
28.	21	−0·13	+0·04	−0·10	−0·15	−0·18	−0·17	−0·07	+0·12	+0·07	−0·20	−0·15	−0·17	−0·16	−0·02	+0·04	+0·03		+0·01	−0·17			S.W.	N.W.	W.C.	S.W.
29.	9																		+0·03		−0·22	−0·15	N.W.	N.W.	W.	S.W.
29.	22	0·00	−0·08	−0·15	−0·41	−0·05	−0·15	−0·05	0·00	−0·31	−0·09	−0·28	−0·42	−0·14	−0·13	−0·13	−0·16	+0·01	+0·01	−0·09			N.W.	N.W.	W.C.	N.W.
30.	10																	+0·08	+0·05	−0·21			N.E.	N.E.	S.E.C.	W.
30.	22	+0·05	+0·08	+0·07	+0·47	+0·12	+0·14	+0·11	+0·20	+0·31	+0·23	+0·27	+0·05	−0·19	+0·02	−0·01	0·00	+0·01	−0·04	+0·07	−0·13	−0·02	N.E.C.	N.E.	S.W.	S.W.
July 1.	11																		+0·06	+0·01	−0·19	−0·06	S.W.C.	S.E.	S.C.	S.W.
1.	23	−0·14	−0·14	−0·04	+0·33	−0·24	+0·02	−0·11	+0·33	+0·12	+0·14		−0·23	−0·15	+0·10	+0·05	−0·05	+0·03	+0·02	+0·02		−0·16	N.W.	S.W.	W.	W.
2.	12																		+0·03	−0·02	−0·24	−0·11	W.C.	N.W.	N.W.S.	W.N.W.
3.	1	+0·31	+0·30	+0·25	+0·13	+0·28	+0·38	+0·22	+0·22	+0·30	+0·21	+0·28	−0·22	−0·03	+0·17	+0·09	+0·08	+0·13		−0·07			S.W.C.	N.W.	W.	W.
3.	13																		+0·25	+0·45	+0·22	+0·36	−0·47	S.E.S.	W.S.W.S.	S.E.	S.E.
4.	2	+0·76	+0·81	+0·86	+0·80	+0·85	+0·95	+0·88	+0·84	+0·78	+0·74	+0·51	+0·42	+0·73	+0·87	+0·77	+0·62	+0·71					S.W.C.	S.W.	S.C.	
4.	14																		+0·96	+0·80	+0·82	+0·65	+0·59	S.W.	S.W.	S.W.S.	S.W.
5.	3	−0·16	+0·07	+0·19	−0·10	0·00	+0·06	+0·13	+0·39	+0·38	+0·47	+0·58	+0·57	+0·62	+0·50	+0·26	+0·39							S.W.	S.C.	W.S.W.
5.	15																		+0·77	+0·21	+0·45	−0·02	−0·03	N.W.	N.W.S.	W.	N.W.
6.	4	−0·22	−0·24	−0·30	−0·37	−0·18	−0·37	−0·17	−0·34	−0·37	−0·32	−0·36	−0·40	−0·25	−0·31	−0·25	−0·29	−0·31			−0·44	−0·41	−0·29	N.W.C.	N.W.	W.S.	N.W.
6.	16																		−0·25	−0·44				S.W.C.	N.E.	W.C.	S.W.
7.	4	+0·35	+0·31	+0·30	+0·46	+0·37	+0·42		+0·74	+0·15	+0·16	+0·34	+0·25	+0·04	+0·18		+0·14	+0·08	+0·58		+0·20	+0·17	−0·03	S.	S.W.	E.	S.W.
7.	17																							W.S.	S.W.S.	N.W.	
8.	5	+0·40	+0·46	+0·49	+1·00	+0·41	+0·53	+0·25	+0·29	+0·30	+0·28	+0·54	+0·30	+0·25	+0·38	+0·51	+0·35	+0·40		+0·23	+0·37	+0·01		N.W.S.	S.E.	S.W.	S.W.
8.	18																							N.W.S.	E.N.E.	S.E.S.	N.W.
9.	6	+0·31	+0·19	+0·22	+0·71	+0·24	+0·35	+0·43	+0·00	+0·38	+0·43	+0·45	+0·36	+0·19	+0·17	+0·04	+0·27	+0·06	+0·02	+0·10	+0·12	−0·12	−0·18	N.W.	S.E.	S.	S.W.
9.	18																							N.W.	S.E.	W.	W.
10.	7	+0·33	+0·42	+0·20	+0·53	+0·23	+0·31	+0·42	+0·52	+0·45	+0·56	+0·29	+0·48	+0·37	+0·35	+0·18	+0·28	+0·22	−0·01	+0·17	+0·29	+0·26	−0·11	S.W.	W.	W.	W.S.W.
10.	19																							S.W.	W.	S.W.S.	S.S.W.
11.	8	+0·47	+0·58	+0·52	+0·75	+0·39	+0·35	+0·35	+0·44	+0·58	+0·57	+0·41	+0·60	+0·56	+0·54	+0·57	+0·69	+0·57	+0·99	+0·58	+1·00	+0·63	+0·47	N.W.	N.E.	S.W.C.	N.W.
11.	20	+0·14	+0·26	+0·25	+0·35	+0·18	+0·16	+0·13	−0·12	−0·08	+0·11	−0·16	+0·07	+0·13	+0·10	+0·03	+0·03	−0·10	−0·15	−0·10	+0·30	−0·03	−0·10	N.W.	N.E.	N.W.	N.W.
12.	8																							N.W.	E.S.E.	S.W.C.	W.
12.	21	−0·19	−0·09	+0·22	+0·92	−0·04	+0·04	+0·03	−0·09	−0·09	+0·43	−0·05	+0·14	+0·39	+0·33	+0·15	+0·08	−0·07	−0·04	−0·19	+0·23	−0·23	−0·33	S.W.	S.W.	S.	S.W.
13.	9													−0·12	−0·24	−0·18	−0·54	−0·28						S.W.	S.W.	S.W.S.	S.W.
13.	22	−0·39	−0·44	−0·41	−0·20	−0·41	−0·49	−0·52	−0·41	−0·35	−0·61	−0·38	−0·61	−0·61	−0·55	−0·48	−0·42	−0·40	−0·55	−0·47	−0·35	−0·43	−0·60	S.W.	S.W.	S.W.	S.W.
14.	10																							N.W.	W.S.W.	W.	W.
14.	23	−0·26	−0·34	−0·47	−0·74	−0·40	−0·43	−0·28	−0·40	−0·59	−0·68	−0·66	−0·65	−0·27	−0·14	−0·10	−0·12	+0·03	−0·05	−0·32	−0·51	−0·36		N.W.	W.S.W.	S.W.	N.W.
15.	11																							S.E.	S.E.	S.	S.E.
15.	23	+0·36	+0·19	−0·02	−0·51	+0·27	+0·05	+0·30	+0·02	−0·09	−0·20	−0·08	−0·07	+0·29	+0·07	+0·13	−0·16	+0·23	+0·43	+0·19	+0·07	+0·30	+0·32	S.E.	S.E.	S.	S.E.
16.	12																		+0·48					S.E.S.	S.E.	E.S.	S.E.
17.	1	+0·35	+0·26	+0·17	−0·10	+0·29	+0·15	+0·28	+0·14	+0·13	+0·01	+0·39	+0·29	+0·07	+0·13				+0·26	+0·37	+0·24	+0·38	+0·20	S.E.	S.E.S.	S.E.S.	S.
17.	13																		+0·27					S.W.	S.E.S.	S.S.	S.W.
18.	2	+0·15	+0·16	+0·11	−0·27	+0·22	+0·05	+0·15	+0·09	−0·12	−0·21	+0·33	+0·04	−0·10	+0·10	+0·05	+0·04	+0·23	+0·18	+0·28	+0·18	+0·34	+0·27	S.W.C.	S.E.	S.W.S.	S.W.
18.	14																		+0·06					S.W.C.	E.S.E.	S.E.S.	S.W.
19.	3	+0·07	+0·01	0·00	−0·27	+0·10		+0·08	−0·08	−0·11	−0·31		−0·04	−0·14	−0·09	+0·02	−0·12	+0·06	+0·27	+0·22	+0·05	+0·21	+0·21	N.E.	S.E.	S.W.C.	S.W.
19.	16	+0·11	+0·02	0·00	−0·20	0·00	−0·04	+0·03	−0·04	−0·12	−0·16	+0·07	−0·02	−0·29	−0·17	−0·08	0·00	+0·11	+0·18					N.E.C.	E.N.E.	S.E.S.	S.E.
20.	4																		+0·19	+0·22	+0·05	+0·26	+0·11	N.E.C.	N.E.	S.S.W.C.	S.W.
20.	16	−0·11	−0·20	−0·18	−0·19	−0·10	−0·25	−0·19	−0·10	−0·24	−0·15	−0·06	−0·13	−0·44	−0·19	−0·12	−0·11	−0·13	+0·07					N.E.C.	N.E.	N.E.S.	N.
21.	5																		+0·17	+0·22	−0·10	−0·04	+0·02	N.E.C.	N.W.	N.E.	N.W.
21.	17	−0·09	−0·15	−0·16	−0·15	−0·15	−0·20	−0·24	−0·45	−0·36	−0·25	−0·15	−0·22	−0·46	−0·25	−0·18	−0·16	−0·13	−0·02	−0·05				N.N.W.C.	N.W.	S.E.C.	N.W.
22.	6																		−0·16	0·00	−0·05	+0·04	+0·14	S.E.C.	N.W.	S.W.	N.W.
22.	18	−0·14	−0·16	−0·10	−0·07	−0·11	−0·13	−0·19	−0·26	−0·24	−0·15	−0·09	−0·18	−0·48	−0·33	−0·26	−0·15	−0·25	−0·31					N.E.C.	N.W.	S.E.	S.W.
23.	6																			−0·10	−0·10	−0·07	−0·04	N.E.C.	S.W.	S.S.E.	N.W.
																								N.W.C.	E.N.E.	S.E.C.	S.S.E.

Approximate time of high water at Kilbaha.		Excess of each value of A_0 above the mean value of A_0 at every station.																						Wind.			
		Kilbaha.	Kilrush	Foynes Island.	Limerick.	Caslch Bay.	Galway.	Old Head.	Mullaghmore.	Buncrana.	Port Rush.	Carrowkeel.	Ballycastle.	Glenarm.	Donaghadee.	Ardglass.	Clogher Head.	Kingstown.	Courtown.	Dunmore East.	New Ross.	Passage West.	Castle Townsend.	Kilbaha.	Port Rush.	Kingstown.	Passage West.
	hrs.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.				
July 23.	18	−0·18	−0·13	−0·19	−0·10	−0·05	−0·23	−0·23	−0·22	−0·19	−0·15	−0·15	−0·23	−0·46	−0·29	−0·24	−0·29	−0·20	−0·31	−0·11	−0·15	−0·02	0·00	N.E.c.	N.E.	E.c.	N.W.
24.	7				−0·23																			N.E.c.	N.E.	S.W.	S.W.
24.	19	−0·07	−0·08	−0·12		−0·12	−0·24	−0·08	−0·14	−0·14	−0·20	−0·11	−0·27	−0·40	−0·28	−0·24	−0·02	−0·30	−0·12	−0·01	−0·15	0·00	−0·02	N.W.c.	N.W.	N.W.	N.W.
25.	7				−0·31							−0·28	−0·41											N.W.c.	N.W.	E.c.	S.W.
25.	19	−0·17	−0·23	−0·25		−0·27	−0·34	−0·29	−0·51	−0·44	−0·35			−0·39	−0·26	−0·20	−0·27	−0·20	−0·26	−0·06	−0·15	−0·09	−0·06	E.c.	N.W.	N.	N.W.
26.	8																		−0·26					E.c.	N.W.	N.W.	N.W.
26.	20	−0·34	−0·46	−0·41	−0·55	−0·42	−0·60	−0·38	−0·50	−0·53	−0·50	−0·52	−0·54	−0·58	−0·40	−0·32	−0·32	−0·24	−0·22	−0·18	−0·26	−0·15	−0·07	N.E.	N.W.	N.E.	N.W.
27.	8																		−0·29					N.E.	W.N.W.s.	W.s.	N.E.
27.	21	−0·37	−0·49	−0·40	−0·46	−0·41	−0·58	−0·38	−0·36	−0·36	−0·34	−0·47	−0·29	−0·51	−0·25	−0·25	−0·15	−0·23	−0·21	−0·26	−0·38	−0·34	−0·25	N.E.	W.N.W.s.	N.W.s.	N.W.
28.	9																		−0·26					N.E.	N.E.s.	N.s.	N.N.E.
28.	21	−0·48	−0·64	−0·58	−0·79	−0·54		−0·54	−0·56	−0·58	−0·66	−0·51	−0·46	−0·77	−0·55	−0·43	−0·24	−0·31	−0·19	−0·29	−0·54	−0·21	−0·09	N.E.c.	N.E.s.	N.s.	N.N.E.
29.	9																		−0·27					N.E.c.	N.E.s.	N.s.	N.N.E.
29.	22	−0·33	−0·42	−0·40	−0·44	−0·36	−0·47	−0·45	−0·49	−0·38	−0·54	−0·57	−0·35	−0·67	−0·44	−0·37	−0·32	−0·30	−0·25	−0·17	−0·50	−0·18	−0·14	N.W.c.	N.W.	N.W.s.	N.N.E.
30.	10																		−0·32					N.W.c.	N.W.	N.W.s.	N.W.
30.	22	−0·40	−0·46	−0·50	−0·71	−0·48	−0·52	−0·51	−0·63	−0·34	−0·32	−0·38	−0·41	−0·40	−0·44	−0·38	−0·45	−0·35	−0·38	−0·32	−0·58	−0·30	−0·16	N.c.	N.W.	N.W.s.	N.
31.	11																		−0·42					N.W.c.	N.W.	S.S.E.c.	N.W.
31.	23	−0·20	−0·30	−0·29	−0·54	−0·27	−0·31	−0·24	−0·42	−0·16	−0·29	−0·10	−0·45	−0·26	−0·28	−0·34	−0·27	−0·28	−0·26	−0·19	−0·39	−0·10	−0·04	S.E.c.	S.W.	S.E.c.	S.W.
August 1.	12																		−0·10					S.W.	W.S.W.s.	N.E.c.	S.W.
2.	1	+0·10	+0·15	+0·02	−0·21	+0·12	+0·10	+0·05	+0·11	+0·28	+0·12	−0·09	−0·03	+0·30	+0·14	−0·01	+0·03	+0·01	−0·06	+0·06	−0·08	+0·11	+0·16	S.W.c.	W.S.W.s.	S.s.	S.S.W.
2.	14																		−0·21					N.W.	N.W.	S.W.c.	S.E.
3.	3	−0·27	−0·12	−0·18	−0·53	−0·25	−0·19	−0·25	−0·20	−0·16	−0·38	−0·28	−0·21	+0·12	−0·05	−0·14	+0·12	−0·14	−0·31	−0·11	−0·34	−0·10	−0·02	N.	N.E.	N.E.	N.W.
3.	15																		−0·15					S.W.	S.W.s.	W.	S.W.
4.	4	−0·20	−0·10	−0·02	0·00	−0·06	+0·06	−0·16		+0·20	+0·05	+0·15	+0·26	+0·35	+0·15	+0·13	+0·23	+0·05	−0·16	−0·14	−0·24	−0·23	−0·11	N.W.	W.N.W.c.	W.s.	N.W.
4.	16													+0·60					+0·13					S.W.	S.W.s.	W.s.	S.W.
5.	5	+0·03	+0·20	+0·20	+0·44	+0·19		+0·52	+0·27	+0·39	+0·44	+0·32	+0·54		+0·41	+0·31	−0·31	+0·28	+0·10	+0·04	+0·08	−0·08	−0·05	N.W.	W.S.W.s.	W.s.	S.W.
5.	17													+0·36	+0·16	+0·19	+0·18	+0·12	−0·05	+0·08	+0·04	+0·04	+0·07	W.S.W.	W.N.W.s.	S.W.	W.
6.	5	+0·05	+0·24	+0·20	+0·37	+0·17	+0·49	+0·40	+0·51	+0·37	+0·28	+0·36	+0·35											S.W.	W.N.W.s.	S.W.s.	S.W.
6.	18													+0·58	+0·35	+0·33	+0·27	+0·23	+0·02	+0·10	+0·31	+0·04	+0·06	S.W.s.	S.W.s.	S.S.E.c.	S.W.
7.	6	+0·15	+0·36	+0·35	+0·76	+0·31	+0·46		+0·60	+0·42	+0·47	+0·52	+0·59											S.W.	W.S.W.s.	S.W.	W.
7.	19				+0·34									+0·43	+0·05	+0·11	−0·10	−0·09	−0·17	+0·03	+0·41	+0·03	+0·02	S.	S.E.s.	E.	S.W.
8.	7	+0·24	+0·32	+0·59		+0·34	+0·37		0·00	+0·27	+0·34	+0·53	+0·31											S.W.	S.W.	S.S.E.s.	S.W.
8.	19				+0·42							+0·35		+0·45	+0·19	+0·16	−0·08	+0·15	+0·01	+0·16	+0·39	+0·20	+0·20	S.c.	S.W.	E.	S.W.
9.	8	+0·29	+0·25	+0·38		+0·20	+0·21	+0·18	+0·17	+0·31	+0·31		+0·36											S.W.	E.S.E.c.	S.c.	S.W.
9.	20				+0·51							+0·16	+0·06	+0·52	+0·20	+0·13	+0·11	+0·14	+0·68	+0·17	+0·40	+0·14	+0·14	N.W.c.	S.W.c.	S.E.	S.W.
10.	8	+0·11	+0·07	+0·30		+0·10	+0·06	+0·12	+0·41	+0·31	+0·19													N.W.c.	N.W.	W.s.	N.W.s.
10.	21				−0·05				−0·16			−0·28	−0·18	+0·33	+0·10	+0·09	+0·28	+0·03	−0·07	−0·15	+0·03	−0·11	+0·04	S.W.c.	W.S.W.	N.W.s.	W.S.W.
11.	9	−0·02	−0·08	−0·05	+0·08	−0·02	0·00	−0·14		−0·03	−0·15			+0·32	+0·10	+0·16	0·00	+0·09						N.W.c.	N.W.	S.E.	S.W.
11.	21											−0·31	−0·01						−0·01	−0·11	+0·14	−0·07	−0·12	S.W.c.	S.W.s.	S.	S.W.
12.	10	−0·01	−0·06	+0·04	+0·12	+0·01		−0·10			+0·11			+0·15	−0·07	−0·02	+0·01	−0·11	0·00					S.W.c.	W.S.W.	S.E.	S.W.
12.	22	−0·24	−0·27	−0·25	−0·47	−0·15	−0·35	−0·23	−0·11	−0·08	−0·14	−0·45	+0·07						−0·37	−0·30	−0·41	−0·32	−0·23	S.W.c.	W.S.W.s.	S.W.	S.W.
13.	11												+0·02	−0·20	−0·33	−0·30	+0·10	−0·30	−0·34					S.W.c.	W.S.W.s.	S.E.	S.W.
13.	23	−0·38	−0·46	−0·46	−0·78	−0·40	−0·36	−0·36	−0·34	−0·31	−0·33	−0·55							−0·43	−0·44	−0·64	−0·44	−0·26	S.W.c.	S.W.s.	S.E.c.	S.W.
14.	12												−0·24	−0·29	−0·37	−0·36	−0·10	−0·25	−0·34					S.W.c.	S.W.c.	W.c.	S.W.
15.	0	−0·38	−0·37	−0·46	−0·79	−0·34	−0·44	−0·47	−0·49	−0·44	−0·49	−0·47							−0·31	−0·27	−0·48	−0·29	−0·22	N.W.c.	N.W.	S.S.E.	N.W.
15.	13												−0·30	−0·36	−0·39	−0·48	−0·42	−0·15	−0·34					N.E.c.	N.W.	N.E.c.	N.W.
16.	1	−0·24	−0·20	−0·41	−0·80	−0·25	−0·33	−0·28	−0·43	−0·41	−0·51								−0·28	−0·26	−0·46	−0·17	−0·12	E.	N.E.	N.E.c.	S.E.
16.	15																		−0·08					S.E.	S.S.E.	N.E.	S.E.
17.	3	−0·06	+0·09	−0·12	−0·45	−0·03		−0·01	−0·14	+0·06	−0·04	+0·02	0·00	0·00	−0·02	−0·01	+0·22	+0·16	−0·32	+0·17	−0·22	+0·09	+0·13		N.E.	E.	S.	
17.	15																		+0·15					N.E.c.	N.E.	E.c.	S.E.
18.	4	−0·01	−0·05	−0·07	−0·32	+0·01	−0·13	−0·11	−0·14	−0·03	−0·10	0·00	−0·02	−0·03	−0·09	−0·06	−0·03	+0·02	−0·05	+0·20	−0·11	+0·24	+0·29		N.E.	S.E.c.	S.	
18.	16													+0·21	+0·15	+0·19	+0·24	+0·20	+0·44					N.W.c.	N.E.	S.E.c.	N.W.
19.	5	+0·11	+0·11	+0·10	+0·08	+0·14	+0·23	+0·10	+0·13	+0·14	+0·16	+0·17	+0·25							+0·32	+0·13	+0·26	+0·16	N.W.c.	N.E.	S.	N.W.
19.	17													+0·46	+0·29	+0·27	+0·44	+0·17							S.E.s.	S.E.c.	S.W.
20.	5	+0·09	+0·09	+0·07	+0·19	+0·14	+0·10	+0·27	+0·39	+0·30	+0·44	+0·26	+0·46							+0·11	+0·09	+0·05	+0·13	S.W.c.	S.W.s.	S.	N.W.
20.	18													−0·05	−0·18	−0·15	−0·41	−0·10	−0·06	−0·06	−0·15	−0·10	−0·02	N.E.c.	S.W.s.	S.W.c.	N.W.
21.	6	−0·11	−0·13	−0·14	−0·07	−0·16	−0·19	−0·62	−0·52	−0·07	−0·12	−0·14	−0·14											N.W.c.	N.W.	N.E.c.	N.W.
21.	18												−0·47	−0·49	−0·58	−0·57	−0·50	−0·63		+0·37	−0·56	−0·44	−0·26	E.c.	S.W.	W.c.	N.W.
22.	6	−0·41	−0·44	−0·45	−0·47	−0·44	−0·50	−0·13	−0·24	−0·29	−0·36	−0·41												N.E.c.	E.N.E.c.	S.E.c.	N.W.
22.	19												+0·03	+0·05	+0·02	−0·10	−0·10	−0·10	−0·05	+0·17	+0·10	+0·08	+0·03	S.W.c.	S.E.	N.E.c.	N.N.W.
23.	7	−0·07	−0·02	−0·08	−0·02	−0·07	−0·07	−0·11	−0·27	+0·27	+0·17													S.W.	W.S.W.	E.c.	W.

Upon inspecting these numbers, one law cannot fail to occur to us, namely, that the irregularities are nearly the same in magnitude and in sign on every part of the coast of Ireland at the same time. So prevalent is this law, that there are few instances in which the irregularity at one place differs from the mean of the irregularities at all the places at the same time by more than an inch. My ideas of the almost perfect fluidity of water have been very much raised by this comparison. I may remark that it embodies, in a form admitting of easy examination, the result concluded from rough inspection of observations which is made the foundation of a method for supplying deficient observations described in page 10. I may also add that it gives no small security for the general fidelity and accuracy of the observers at the different stations.

I do not perceive any certain connexion between the irregularities and the course of the winds, except that the water is usually highest on all parts of the coast with a violent south-west wind.

In order to ascertain the general relation of these irregularities to those of the barometer, I have compared the corrected mean height of the barometer at Greenwich for each civil day with the mean height for the year (using the numbers published in the Greenwich Magnetical and Meteorological Observations). The following are the results:—

Excess of the corrected mean height of the barometer each day, at Greenwich, above the mean height for the year 1842.

	in.		in.		in.		in.		in.		in.
June 23.	−0·142	July 4.	−0·226	July 15.	+0·378	July 26.	+0·042	Aug. 6.	−0·033	Aug. 17.	+0·132
24.	−0·251	5.	−0·232	16.	+0·174	27.	+0·187	7.	....	18.	−0·041
25.	−0·234	6.	+0·129	17.	....	28.	+0·056	8.	+0·078	19.	−0·067
26.	....	7.	+0·070	18.	−0·118	29.	−0·069	9.	+0·017	20.	+0·032
27.	+0·218	8.	−0·216	19.	−0·147	30.	+0·083	10.	−0·263	21.	....
28.	+0·268	9.	−0·271	20.	−0·231	31.	....	11.	−0·029	22.	−0·023
29.	+0·097	10.	....	21.	−0·189	Aug. 1.	+0·310	12.	+0·313	23.	−0·064
30.	−0·080	11.	−0·288	22.	+0·064	2.	+0·164	13.	+0·443		
July 1.	−0·168	12.	−0·046	23.	+0·235	3.	−0·016	14.	....		
2.	−0·105	13.	+0·226	24.	....	4.	−0·092	15.	+0·242		
3.	....	14.	+0·388	25.	−0·040	5.	−0·036	16.	+0·207		

I have also obtained, through the kindness of Sir W. R. Hamilton, the barometrical observations at the Observatory of Dunsink, near Dublin; and from Colonel Colby and Captain Larcom, R.E., I have received the observations made in the Phœnix Park near Dublin, and at Limerick. The following results are obtained by comparing each day's mean with the mean for this period.

Excess of the mean height of the barometer each day, at Dublin, above the mean of all.

	Dunsink.	Phœnix Park.		Dunsink.	Phœnix Park.		Dunsink.	Phœnix Park.		Dunsink.	Phœnix Park.		Dunsink.	Phœnix Park.		Dunsink.	Phœnix Park.
	in.	in.		in.	in.		in.	in.		in.	in.		in.	in.		in.	in.
June 23.	−0·31	−0·373	July 4.	−0·53	−0·547	July 15.	+0·35	+0·388	July 26.	+0·19	+0·164	Aug. 6.	−0·04	−0·070	Aug 17.	+0·09	+0·059
24.	−0·49	−0·454	5.	−0·22	−0·361	16.	+0·04	+0·076	27.	+0·31	+0·209	7.	.....	−0·112	18.	+0·01	−0·013
25.	−0·49	−0·534	6.	+0·06	+0·173	17.	.....	−0·196	28.	+0·20	+0·189	8.	−0·06	−0·097	19.	−0·17	−0·210
26.	+0·06	−0·098	7.	−0·22	−0·237	18.	−0·13	−0·153	29.	+0·20	+0·173	9.	−0·10	−0·111	20.	−0·08	−0·105
27.	+0·31	+0·315	8.	−0·38	−0·500	19.	−0·12	−0·165	30.	+0·29	+0·284	10.	−0·21	−0·258	21.	+0·12	+0·115
28.	+0·16	+0·148	9.	−0·32	−0·365	20.	−0·11	−0·147	31.	.....	+0·365	11.	−0·01	−0·011	22.	+0·17	+0·165
29.	+0·13	+0·190	10.	−0·25	−0·180	21.	+0·01	−0·006	Aug. 1.	+0·32	+0·315	12.	+0·17	+0·170	23.	−0·07	−0·079
30.	+0·02	+0·022	11.	−0·43	−0·485	22.	+0·22	+0·205	2.	+0·09	+0·072	13.	+0·49	+0·418			
July 1.	−0·10	−0·136	12.	−0·09	−0·074	23.	+0·30	+0·304	3.	+0·10	+0·089	14.	.....	+0·445			
2.	−0·04	−0·059	13.	+0·14	+0·121	24.	.....	+0·200	4.	−0·09	−0·110	15.	+0·37	+0·342			
3.	−0·25	−0·108	14.	+0·45	+0·443	25.	+0·09	+0·061	5.	−0·14	−0·178	16.	+0·29	+0·264			

Excess of the mean height of the barometer each day, at Limerick, above the mean of all.

	in.		in.		in.		in.		in.		in.
June 23.	−0·407	July 4.	−0·543	July 15.	+0·365	July 26.	+0·182	Aug. 6.	−0·062	Aug. 17.	+0·058
24.	−0·447	5.	−0·169	16.	−0·059	27.	+0·324	7.	−0·169	18.	−0·002
25.	−0·535	6.	+0·212	17.	−0·320	28.	+0·295	8.	−0·171	19.	−0·198
26.	−0·077	7.	−0·217	18.	−0·208	29.	+0·220	9.	−0·152	20.	−0·115
27.	+0·360	8.	−0·514	19.	−0·178	30.	+0·337	10.	−0·267	21.	+0·099
28.	+0·178	9.	−0·346	20.	−0·132	31.	+0·381	11.	−0·053	22.	+0·190
29.	+0·178	10.	−0·191	21.	+0·030	Aug. 1.	+0·323	12.	+0·122	23.	−0·069
30.	+0·039	11.	−0·491	22.	+0·173	2.	+0·052	13.	+0·406		
July 1.	−0·072	12.	−0·104	23.	+0·308	3.	+0·124	14.	+0·422		
2.	+0·022	13.	+0·094	24.	+0·206	4.	−0·051	15.	+0·360		
3.	−0·116	14.	+0·440	25.	+0·074	5.	−0·162	16.	+0·301		

The comparison of these numbers with the irregularities in the heights of the water amply supports the law of Daussy, Whewell, and Bunt, that a negative irregularity in the height of the barometer is accompanied by a positive irregularity in the height of the sea, twelve or fourteen times as great as that of the barometer.

Section XII.—*Discussion of range of tide, or coefficient of first arc in the analysis of individual tides; and of semimenstrual inequality in range, apparent proportion of solar and lunar effects, and age of tide as deduced from range.*

The tides were divided into groups of large tides and small tides, separated at the same times as those particularized in pages 29 and 96. For each of these groups the mean of the values of C_1 was taken, some deficient values being supplied by interpolation. The moon's parallax and the square of the cosine of the moon's and sun's declinations were taken for two days preceding each tide, and the means of these quantities were taken through the same groups.

A general result will be obtained by forming the sum of the mean values of C_1 for all the stations in each group. Thus we obtain:—

Large Tides.

Period.	Sum of mean values of C_1 at all the stations.	Mean value of $\cos^2$ moon's declination.	Mean value of moon's parallax.	Mean value of $\cos^2$ sun's declination.
h h	ft.		′ ″	
July 6. 16 to July 13. 3	117·43	0·8742	59 44	0·8547
July 20. 9 to July 28. 9	100·11	0·9076	54 41	0·8815
Aug. 5. 0 to Aug. 11. 16	129·11	0·9260	60 31	0·9194

Small Tides.

Period.	Sum of mean values of C_1 at all the stations.	Mean value of $\cos^2$ moon's declination.	Mean value of moon's parallax.	Mean value of $\cos^2$ sun's declination.
h h	ft.		′ ″	
June 28. 6 to July 6. 16	71·66	0·9427	55 13	0·8456
July 13. 3 to July 20. 9	84·63	0·9202	58 19	0·8666
July 28. 9 to Aug. 5. 0	73·40	0·8965	55 56	0·9012
Aug. 11. 16 to Aug. 18. 15	77·84	0·8697	57 34	0·9378

Put M for the lunar effect when the square of the cosine of the moon's declination is 0·9 and her parallax is 57′; m for the quantity by which this is increased for every increase of 1′ in parallax; s for the mean effect of the sun (the square of the cosine of his declination being 0·9) for one-fourth of a lunation, positive in the large tides and negative in the small tides, which bears to the absolute effect of the sun a relation explained in page 34. The effect of the variations of the moon's parallax and declination upon the luni-solar tide, as is well known, is nearly the same as that on the simple lunar tide; and therefore it will be correct to refer the mean of the luni-solar tides to the mean of the moon's parallaxes and square of cosine of declinations. The variations depending on the moon's declinations are not strictly in the proportion of the squares of the cosines of her declination, but in the present instance, where the means of the squares of the cosines are very nearly equal, may be assumed to be so without sensible error. Forming then an equation from each of the lines in the Table above by these considerations; reducing them to four equations by retaining the second, taking the mean of the first and third, the mean of the fourth and sixth, and the mean of the fifth and seventh, and combining these so as to form three favourable equations, by adding all, by subtracting the sum of the third and fourth from the sum of the others, and by subtracting the sum of the second and third from the sum of the others, we obtain the following equations:—

$$\begin{aligned} 377{\cdot}15 &= \mathrm{M}\times 4{\cdot}024 + m\times 0{\cdot}33 - s\times 0{\cdot}008 \\ 69{\cdot}61 &= -\mathrm{M}\times 0{\cdot}008 + m\times 1{\cdot}29 + s\times 3{\cdot}938 \\ 31{\cdot}87 &= -\mathrm{M}\times 0{\cdot}036 + m\times 7{\cdot}83 - s\times 0{\cdot}026. \end{aligned}$$

From these we obtain M=93·4, m=4·56, s=16·37. The moon's effect, therefore, for the parallax $57'+n'$ may be represented by $93{\cdot}4+4{\cdot}56\times n$. If the moon's hydrodynamical effect varied as the cube of her parallax (which is the law of variation of her statical effect), the formula would be $93{\cdot}4+4{\cdot}92\times n$. The result of the movement of the water has therefore been, to reduce the elliptic variation of lunar effect by $\frac{0{\cdot}36}{4{\cdot}92}$ part, or by $\frac{3}{41}$ part.

Now it is shown in the Encyclopædia Metropolitana, *Tides and Waves*, Art. 448, that if the tides were created by the effect of the moon on the water in a uniform channel surrounding the earth, and if b were the earth's radius, k the depth of the water, g the acceleration produced by gravity in the unit of time, n' the moon's apparent angular motion round the earth (as estimated by a spectator who supposes that the earth does not revolve on an axis), and h the moon's angular motion from her perigee; then the elliptic variation is changed by $\frac{4}{3}\cdot\frac{n'b^2h}{n'^2b^2-gk}$ part. Thus we obtain

$$\frac{4}{3}\cdot\frac{n'b^2h}{n'^2b^2-gk}=-\frac{3}{41}.$$

Making $\frac{h}{n}=\frac{3}{80}$, we find $\frac{gk}{n'^2b^2}=\frac{101}{60}=\frac{5}{3}$ nearly; and $k=\frac{5}{3}\cdot\frac{n'^2b^2}{g}$. Observing that $n'b$

$=$linear velocity of a point at the equator produced by the earth's rotation, supposing the moon fixed, we easily find $\frac{n^2b^2}{g}=13$ miles nearly; and thus our observations give

$$\text{Depth of the sea} = k = 22 \text{ miles.}$$

If the channel were supposed to be a small circle of the earth instead of a large one, the resulting depth of the sea would be diminished in the proportion of the square of its diameter.

Whatever may be supposed of the error of this result, or the inapplicability of the theory by which it is obtained to the circumstances of the seas, I may remark that it agrees generally with a result deduced from Mr. WHEWELL's discussions of the observations at Bristol with reference to the moon's declinations*.

Assuming however that we have correctly determined $\frac{n^2b^2}{gk}=\frac{3}{5}$, we may proceed to remark that† the moon's hydrodynamical effect is represented by her statical effect multiplied by $\frac{1}{gk-n^2b^2}$ and by constants; and that the sun's hydrodynamical effect is represented by his statical effect multiplied by $\frac{1}{gk-n'^2b^2}$ and by the same constants. If we consider $\frac{n^2}{n'^2}=\frac{15}{14}$, then the hydrodynamical effect of the moon contains the multiplier

$$\frac{1}{gk}\cdot\frac{1}{1-\frac{3}{5}}=\frac{1}{gk}\cdot\frac{5}{2} \text{ or } \frac{1}{gk}\cdot\frac{25}{10},$$

while that for the sun contains the multiplier

$$\frac{1}{gk}\cdot\frac{1}{1-\frac{15}{14}\cdot\frac{3}{5}}=\frac{1}{gk}\cdot\frac{14}{5} \text{ or } \frac{1}{gk}\cdot\frac{28}{10}.$$

And therefore the proportion of the moon's statical effect to the sun's is greater than the proportion of her dynamical effect to the sun's in the ratio of 28 to 25. And as the moon's hydrodynamical effect, deduced from the values of M and s above (93·4 and 16·37), by the considerations in page 34, is nearly $=\frac{1\cdot00}{0\cdot28}\times$ sun's hydrodynamical effect, it follows that the moon's statical effect $=\frac{1\cdot00}{0\cdot25}\times$ sun's statical effect $=4\times$ sun's statical effect. This conclusion differs widely from LAPLACE's; yet it is formed, as I believe, on grounds as good as LAPLACE's.

For particular results applying to each individual station, regarding the semi-menstrual inequality in range and the apparent proportion of the solar and lunar hydrodynamical effects; the mean value of C_1 for large tides is found by taking the mean of the three values in the three periods of the last Table, and the mean value for small tides by taking the mean of the four values in the four periods of the last

* Tides and Waves, Art. 553. † Ibid. Art. 448.

Table; and then treating these in the same manner as in the latter part of the table on page 35.

Station.	Mean of C_1 for large tides.	Mean of C_1 for small tides.	Difference.	Mean, or M.	Difference divided by mean.	Corresponding value of $\frac{S}{M}$.
	ft.	ft.	ft.	ft.		
Kilbaha	6·12	3·73	2·39	4·93	0·48	0·40
Kilrush	6·54	4·19	2·35	5·37	0·44	0·36
Foynes Island....	7·35	4·96	2·39	6·16	0·39	0·32
Limerick.....	8·98	6·21	2·77	7·59	0·37	0·30
Casleh Bay.....	6·35	3·83	2·52	5·09	0·50	0·42
Galway	6·41	3·89	2·52	5·15	0·49	0·41
Old Head	5·59	3·43	2·16	4·51	0·48	0·40
Mullaghmore	5·35	3·25	2·10	4·30	0·49	0·41
Buncrana	5·84	3·37	2·47	4·61	0·54	0·46
Port Rush	2·56	1·38	1·18	1·97	0·60	0·52
Carrowkeel.....	3·35	1·95	1·40	2·65	0·53	0·45
Ballycastle	1·42	0·88	0·54	1·15	0·47	0·39
Glenarm	2·89	2·47	0·42	2·68	0·16	0·12
Donaghadee	5·24	3·96	1·28	4·60	0·28	0·22
Ardglass.....	6·90	4·96	1·94	5·93	0·33	0·26
Clogher Head ..	6·79	4·81	1·98	5·80	0·34	0·27
Kingstown	5·26	3·69	1·57	4·48	0·35	0·28
Dunmore East ..	5·73	3·91	1·82	4·82	0·38	0·31
New Ross	6·16	4·51	1·65	5·34	0·31	0·25
Passage West....	5·94	4·19	1·75	5·07	0·35	0·28
Castle Townsend..	4·79	3·33	1·46	4·06	0·36	0·29

For the age of tide as inferred from range, the times have been ascertained (by interpolating between the times in the Tables of formulæ in Section X.) at which the actual value of C_1 may be supposed to coincide with the mean value of C_1; and the times thus found have been compared with the times at which the moon's hour-angle from the sun was 3^h, 9^h, 15^h, 21^h, namely, June 26, 6^h, July 4, 16^h, July 11, 3^h, July 18, 9^h, July 26, 9^h, August 3, 0^h, August 9, 16^h, and August 16, 15^h. An error is here committed alternately + and −, and therefore it is proper to use an even number of comparisons. Eight are used at every place except Ballyeastle and Glenarm, where only six are used. [It is to be remarked that in the use of the formulæ in Section X., a number opposite to a bracket is always held to correspond to the mean of the two times embraced by that bracket.] The means of all the differences at each station between the times thus found from Section X. and the times corresponding to the hour-angles 3^h, 9^h, &c., are adopted in the following Table as the age of the tide. These* are the true ages of the tide.

Station.	Age of tide.		Station.	Age of tide.		Station.	Age of tide.	
	d	h		d	h		d	h
Kilbaha	1	20	Mullaghmore	2	0	Ardglass.....	2	2
Kilrush	1	19	Buncrana	1	20	Clogher Head ..	2	2
Foynes Island....	1	21	Port Rush	1	11	Kingstown	2	0
Limerick.....	2	1	Carrowkeel.....	1	14	Dunmore East ..	2	2
Casleh Bay.....	1	20	Ballycastle	1	5	New Ross	2	2
Galway	1	21	Glenarm.....	2	9	Passage West....	2	1
Old Head	1	22	Donaghadee	2	6	Castle Townsend..	1	23

* Tides and Waves, Art. 545.

Section XIII.—*Establishment of each port, as deduced from the time of maximum of the first periodical term in the analysis of individual tides.*

The preceding operations having made it sufficiently clear that the age of the tide differs little from two days, it is proper now to refer all the phenomena of the tide to an epoch two days earlier than the observation. A process is therefore adopted in this section differing in a trifling degree from that in Section VII. The times are taken at which the moon's hour-angle from the sun was 0^h, 6^h, 12^h, 18^h, and two days are added to these times: the resulting times are June 24, 9^h, July 2, 20^h, July 9, 19^h, July 16, 21^h, July 23, 23^h, August 1, 16^h, August 8, 4^h, August 15, 5^h, August 22, 16^h. These times are assumed to divide the large lunitidal intervals from the small ones. For the lunitidal intervals at the high waters of the First Division, the moon's time of Greenwich transit is taken for that transit which precedes the high water by two days and a few hours; for the high waters of the Second Division the moon's time of Greenwich lower transit is interpolated. Comparing these times of transit with the times of high water in the formulæ of Section X., the lunitidal intervals corresponding to lunar transits two days earlier are found. The means of these are taken for the groups separated by the times specified above. Then, the means of the large and the small lunitidal intervals being adopted as the mean interval, a correction of $1^h\ 41^m$ is applied subtractively, to reduce the interval after moon's transit two days previous, to the interval after moon's transit on the same day as the tide ($1^h\ 41^m$ being the difference between two solar days and two lunar days). The result is contained in the following Table.

Station.	Mean of large intervals from transit two days previous.	Mean of small intervals from transit two days previous.	Mean of all the intervals from transit two days previous.	True establishment in Greenwich time.
	h m	h m	h m	h m
Kilbaha	6 53	5 55	6 24	4 43
Kilrush	7 6	6 7	6 36	4 55
Foynes Island....	7 49	6 54	7 21	5 40
Limerick.....	8 19	7 27	7 53	6 12
Casleh Bay.....	7 3	6 3	6 33	4 52
Galway	7 8	6 9	6 38	4 57
Old Head	7 19	6 23	6 51	5 10
Mullaghmore	7 39	6 37	7 8	5 27
Buncrana	8 27	7 21	7 54	6 13
Port Rush	9 4	7 50	8 27	6 46
Carrowkeel.....	9 48	8 44	9 16	7 35
Ballycastle	10 4	9 2	9 33	7 52
Glenarm.....	12 53	12 3	12 28	10 47
Donaghadee	13 10	12 16	12 43	11 2
Ardglass.....	13 14	12 16	12 45	11 4
Clogher Head ..	13 21	12 24	12 52	11 11
Kingstown	13 26	12 30	12 58	11 17
Dunmore East ..	7 14	6 16	6 45	5 4
New Ross	8 5	7 11	7 38	5 57
Passage West....	7 26	6 31	6 58	5 17
Castle Townsend..	7 3	6 5	6 34	4 53

Section XIV.—*Semimenstrual inequality in time, proportion of solar and lunar effects from times, and apparent age of tide as shown by times; deduced from the time of maximum of the first periodical term in the analysis of individual tides.*

Taking the difference of the means of large intervals and small intervals in the last Table, we deduce from them the value of $\frac{S}{M}$ by the same formula as that employed in page 42. The results are as follows:—

Station.	Difference of means of large intervals and small intervals.	Value of $\frac{S}{M}$	Station.	Difference of means of large intervals and small intervals.	Value of $\frac{S}{M}$
	m			m	
Kilbaha	58	0·37	Ballycastle	62	0·40
Kilrush	59	0·38	Glenarm	50	0·33
Foynes Island....	55	0·36	Donaghadee	54	0·35
Limerick.....	52	0·34	Ardglass.....	58	0·37
Casleh Bay.....	60	0·39	Clogher Head ..	57	0·37
Galway	59	0·38	Kingstown	56	0·36
Old Head	56	0·36	Dunmore East ..	58	0·37
Mullaghmore	62	0·40	New Ross	54	0·35
Buncrana	66	0·42	Passage West....	55	0·36
Port Rush	74	0·48	Castle Townsend..	58	0·37
Carrowkeel.....	64	0·41			

These are the true values of $\frac{S}{M}$*, supposing that the process for finding them has been correctly followed. I omit here all deductions as to the absolute maximum of semimenstrual inequality in time at each station, for a reason that will be explained in Section XV.

To obtain the apparent age of tide as shown by times, a process was used analogous to that in page 43 or that in page 106. The times were ascertained (by interpolating between the times in the Tables of formulæ in Section X.) at which the actual interval of analysed high water from moon's transit two days previous coincided with the mean interval in the Table of page 107. These times were then compared with the times at which the moon's hour-angle from the sun was 0^h, 6^h, 12^h, 18^h; namely, June 22, 9^h, June 30, 20^h, July 7, 19^h, July 14, 21^h, July 21, 23^h, July 30, 16^h, August 6, 4^h, August 13, 5^h, August 20, 16^h. The difference was considered to be the apparent age of the tide as given by the times. The following are the results:—

Station.	Apparent age of tide from times.	Station.	Apparent age of tide from times.	Station.	Apparent age of tide from times.
	d h		d h		d h
Kilbaha	1 7	Mullaghmore	0 23	Ardglass.....	1 11
Kilrush	1 10	Buncrana	1 4	Clogher Head....	1 11
Foynes Island....	1 22	Port Rush	0 9	Kingstown	1 3
Limerick.....	2 7	Carrowkeel.....	+1 0	Dunmore East ..	2 7
Casleh Bay.....	1 4	Ballycastle	−0 14	New Ross	2 18
Galway	1 3	Glenarm	+1 12	Passage West....	1 23
Old Head	1 6	Donaghadee	1 13	Castle Townsend..	1 11

* Tides and Waves, Art. 538.

The apparent age from times is at every littoral station, except Dunmore, considerably less than the age from range. At Port Rush the apparent age is small; and at Ballycastle, the diminution proceeds so far as to change the sign of the apparent age. I cannot entirely explain this difference. It indicates that large tides arrive earlier (with reference to the hour-angles of the sun and moon) than small ones; but I know not why this should happen.

Section XV.—*Comparison of the results as to mean height, range, semimenstrual inequality in height, age of tide obtained from height, establishment, semimenstrual inequality in time, and age of tide obtained from times, deduced from high and low waters only, in* Sections V., VI., VII., VIII., *with those deduced from the analysis of individual tides in* Sections XI., XII., XIII., XIV.

With regard to the mean heights, we have to compare the results in Section V. with those in Section XI. And first for the mean height on the whole series of observations. The stations which appear best adapted to enable us to decide on the adoption of Mean Heights or Apparent Mean Heights as our standard (that is, as most nearly related to the height of water unaffected by tides) are those upon the Shannon. And these leave no doubt that the Mean Heights (deduced from the analysis) ought to be adopted. In a current river, it is inconceivable that the height at a lower station (as Foynes Island) should be equal to that at the highest station (Limerick), as it would be if we relied on apparent mean heights. These are the only stations which throw much light on this subject, for at Dunmore East and New Ross (river stations) the two results agree; and, at the littoral stations, there is on the whole no difference of a critical kind. At the two quasi-river-stations of Buncrana and Carrowkeel, we have on both systems discordant results, one giving a mean level higher and the other lower than that of the more exposed stations. The extreme diminution of the range of tide between Port Rush and Glenarm causes no sensible alteration of the mean level, in either system of results. The greater elevation of the mean level at the northern part of the island is equally well-marked in both. For the variation of mean height under different circumstances of large and small tides, large and small declinations of the moon, and increasing and decreasing declinations of the moon, the comparison of the numbers on the two systems gives little subject for remark, except that the difference between large and small tides in the Shannon stations seems to be more strongly marked in the mean heights than in the apparent mean heights. This however does not well accord with the idea of a standard height. It will be remarked that at Limerick the difference between the mean height and the apparent mean height is nearly a foot.

With regard to the range of the tide, we have to compare the "Mean Range" in the 8th column of the Table in page 35 with the double of "Mean or M" in the 5th column of the Table on page 106. Neglecting the differences of 0·01, we may assert that, at all the stations except Mullaghmore and Dunmore East, the apparent range

is greater than 2 C_1 in the formulæ of Section X.; and that in the river-stations the difference is considerable. Without accounting for the two exceptions, I may remark that this shows that the departure from the pure form of tide depending on a single sine is, at all the other stations, similar in some important points of its character to that in a river tide. The nature of the tide at each station will be examined more accurately in Section XVI.

With regard to the semimenstrual inequality in height and the apparent value of $\frac{S}{M}$, we have to compare the two last columns of the Table on page 105 with the two similar columns of the Table on page 35. The numbers are so nearly equal that we cannot assert that there is any certain difference. The large value of $\frac{S}{M}$ at Port Rush, the small value at Glenarm, and the general smallness from Donaghadee to Castle Townsend (like that in the river station Limerick) are equally marked in both.

With regard to the age of the tide as obtained from heights or ranges (which, as I have stated before, is the true age of the tide), we must compare the results on page 105 with those on page 38. They agree, on the whole, very well; though the ages deduced from the analysis appear to be somewhat smaller than those deduced from high and low waters. The ages deduced from the analysis also agree better among themselves. The diminution however from Port Rush to Ballycastle is remarkable. The general result seems to be that on the south-western coast of Ireland the age of the tide is about one day twenty hours.

For the establishment, we must compare the Table of page 106 with that of page 39. Only at Limerick and New Ross is the difference considerable: at these stations it amounts to about twenty minutes.

For the semimenstrual inequality in time, we must compare the numbers in page 107 with those of page 42. And here it will at once be remarked that a great and important change has been made in the resulting values of $\frac{S}{M}$ by the new mode of treating them. The values at Old Head and Glenarm and the following stations are increased, and those at Port Rush and Ballycastle are diminished, till they agree sufficiently well with the others. This change arises from two causes. First, the determination of times from the analysis is vastly more accurate than that from the estimation of the times of high and low water. Secondly, in Section VIII. the groups for large intervals and small intervals were divided at each station from a consideration of the magnitudes of the intervals themselves, whereas in Section XIV. they were divided from consideration of a totally different circumstance, namely the age of the tide as shown by the time of occurrence of the mean value of range. Strange as it may appear, the former method was incorrect, and the latter is correct. The former method is affected by a circumstance which ought not to enter into the formation of this result at all, namely the change in the time of station-tide, not depending on the change in the time of sea-tide, but depending on the change which the character of the tidal for-

mula in Section X. undergoes when the magnitude of the range is altered. Thus, the maximum and minimum intervals of sea-tide (which are the objects of our search) occur at the times (corrected for age of tide) when the moon's hour-angle from the sun is 3^h, 9^h, &c. But from hour-angle 9^h to hour-angle 12^h the range of tide is increasing: the modification of time of station-tide as related to time of sea-tide is therefore increasing; a second inequality of time is therefore combined with the first, having a different time of vanishing: the time of vanishing of the compound inequality is therefore different from that of the first inequality, and the maximum magnitude of the compound inequality is different from that of the first. And this produces its full effect if we make our divisions of groups with reference to the time of vanishing of the compound inequality. But if we make our divisions strictly at the times when the first inequality ought to vanish, then, though every individual time be affected by the second inequality, yet there are the same number of instances affected in the same way on opposite sides of our places of division, and their effect disappears in the final result. But as the full compound effect is not used for our final result, conversely we cannot from our final result infer the maximum magnitude of the full compound effect, or the maximum value of the semimenstrual inequality in time.

These considerations appear to be deserving of the utmost attention in investigating the most important single result which can be deduced from the tides, namely the proportion of the hydrodynamical effects of the sun and the moon.

The mean of all the values of $\frac{S}{M}$ in page 108 is 0·38. It is probable that, on attending more scrupulously to the age of the tide at the different stations, results would have been found agreeing more closely with each other: but I think it likely that the mean would scarcely have been altered.

With regard to the apparent age of tide obtained from times, we must compare the numbers in page 108 with those in page 44. The general result of the comparison is, that the mean of the opposite ages deduced from high and low water agrees with that deduced from the analysis as nearly as can be expected (where a small error in the estimated time of high or low water would produce a great effect on the resulting age). They agree in giving a small apparent age at Port Rush and Ballycastle. The ages deduced from range agree also in this. Now this result* is exactly that which would follow from the supposition that a tidal wave with a large range travels more quickly over the shallow bottom than one with a small range: and that this holds not for the phase of high water or low water only, but for the zero of the angle p. Or it would follow from the supposition that a wave of short period travels more quickly than one of long period (the tidal day near conjunction being shorter than that near quadrature). Neither of these points has been established by theory; but the former appears to be very probable.

* Tides and Waves, Art. 463.

Section XVI.—*Remarks on the succeeding terms of the expressions for individual tides, as related to the magnitude of the tide, to the position on the sea-coast, to the position on the river, &c.; comparison with the terms given by the theory of waves; discussion of the quarto-diurnal tide.*

In order to reduce to a smaller number the numerous formulæ of Section X., and to render the relations of their coefficients and arguments at once accurate and distinct, the formulæ have been divided into groups corresponding to large tides and small tides, the times of division being the same as those used in the discussions of the semimenstrual inequality of height. Then, for the large tides, the numbers $\frac{32}{\pi} A_2$ have been collected and their mean has been taken; similarly, the mean of the numbers $\frac{32}{\pi} B_2$ has been taken; and from these, by the treatment described in Section X., a term similar to $C_2 \sin(2 \text{ phase} + \varphi_2)$ is formed. The mean of all the angles φ_1 is also taken, and its double is subtracted from the number corresponding to φ_2. A similar process is used for 3 phase and 4 phase. As for some tides φ_1 is nearly equal to 90° and for others is nearly equal to 270°; the expressions in the latter case are made to admit of combination with those in the former case by subtracting 180° from φ_1 and by changing the signs of A_3 and B_3. The small tides are treated in the same manner. The following Table contains the result.

Variable part of the formulæ for the elevation of the water at each of the Stations in Large Tides and Small Tides.

		ft.	ft.	ft.	ft.
Kilbaha	Large tides.	$6{\cdot}12.\sin p$	$+0{\cdot}16.\sin(2p+164^\circ)$	$+0{\cdot}03.\sin(3p+251^\circ)$	$+0{\cdot}03.\sin(4p+88^\circ)$
	Small tides.	$3{\cdot}73.\sin p$	$+0{\cdot}08.\sin(2p+208^\circ)$	$+0{\cdot}06.\sin(3p+248^\circ)$	$+0{\cdot}01.\sin(4p+120^\circ)$
Kilrush	Large tides.	$6{\cdot}54.\sin p$	$+0{\cdot}19.\sin(2p+104^\circ)$	$+0{\cdot}06.\sin(3p+195^\circ)$	$+0{\cdot}03.\sin(4p+167^\circ)$
	Small tides.	$4{\cdot}19.\sin p$	$+0{\cdot}12.\sin(2p+128^\circ)$	$+0{\cdot}06.\sin(3p+210^\circ)$	$+0{\cdot}02.\sin(4p+175^\circ)$
Foynes Island	Large tides.	$7{\cdot}35.\sin p$	$+0{\cdot}55.\sin(2p+111^\circ)$	$+0{\cdot}26.\sin(3p+162^\circ)$	$+0{\cdot}03.\sin(4p+277^\circ)$
	Small tides.	$4{\cdot}96.\sin p$	$+0{\cdot}37.\sin(2p+124^\circ)$	$+0{\cdot}11.\sin(3p+175^\circ)$	$+0{\cdot}01.\sin(4p+327^\circ)$
Limerick	Large tides.	$8{\cdot}98.\sin p$	$+0{\cdot}90.\sin(2p+75^\circ)$	$+0{\cdot}68.\sin(3p+125^\circ)$	$+0{\cdot}38.\sin(4p+160^\circ)$
	Small tides.	$6{\cdot}21.\sin p$	$+0{\cdot}74.\sin(2p+111^\circ)$	$+0{\cdot}40.\sin(3p+145^\circ)$	$+0{\cdot}15.\sin(4p+182^\circ)$
Casleh Bay	Large tides.	$6{\cdot}35.\sin p$	$+0{\cdot}16.\sin(2p+165^\circ)$	$+0{\cdot}12.\sin(3p+214^\circ)$	$+0{\cdot}06.\sin(4p+348^\circ)$
	Small tides.	$3{\cdot}83.\sin p$	$+0{\cdot}07.\sin(2p+219^\circ)$	$+0{\cdot}07.\sin(3p+238^\circ)$	$+0{\cdot}03.\sin(4p+35^\circ)$
Galway	Large tides.	$6{\cdot}41.\sin p$	$+0{\cdot}18.\sin(2p+157^\circ)$	$+0{\cdot}18.\sin(3p+204^\circ)$	$+0{\cdot}16.\sin(4p+349^\circ)$
	Small tides.	$3{\cdot}89.\sin p$	$+0{\cdot}08.\sin(2p+204^\circ)$	$+0{\cdot}12.\sin(3p+233^\circ)$	$+0{\cdot}04.\sin(4p+38^\circ)$
Old Head	Large tides.	$5{\cdot}59.\sin p$	$+0{\cdot}08.\sin(2p+154^\circ)$	$+0{\cdot}04.\sin(3p+196^\circ)$	$+0{\cdot}04.\sin(4p+282^\circ)$
	Small tides.	$3{\cdot}43.\sin p$	$+0{\cdot}04.\sin(2p+216^\circ)$	$+0{\cdot}10.\sin(3p+257^\circ)$	$+0{\cdot}01.\sin(4p+237^\circ)$
Mullaghmore	Large tides.	$5{\cdot}35.\sin p$	$+0{\cdot}06.\sin(2p+160^\circ)$	$+0{\cdot}07.\sin(3p+14^\circ)$	$+0{\cdot}06.\sin(4p+184^\circ)$
	Small tides.	$3{\cdot}25.\sin p$	$+0{\cdot}04.\sin(2p+217^\circ)$	$+0{\cdot}03.\sin(3p+134^\circ)$	$+0{\cdot}02.\sin(4p+254^\circ)$
Buncrana	Large tides.	$5{\cdot}84.\sin p$	$+0{\cdot}14.\sin(2p+165^\circ)$	$+0{\cdot}08.\sin(3p+262^\circ)$	$+0{\cdot}04.\sin(4p+295^\circ)$
	Small tides.	$3{\cdot}37.\sin p$	$+0{\cdot}04.\sin(2p+199^\circ)$	$+0{\cdot}04.\sin(3p+256^\circ)$	$+0{\cdot}01.\sin(4p+237^\circ)$
Port Rush	Large tides.	$2{\cdot}56.\sin p$	$+0{\cdot}08.\sin(2p+153^\circ)$	$+0{\cdot}12.\sin(3p+257^\circ)$	$+0{\cdot}01.\sin(4p+207^\circ)$
	Small tides.	$1{\cdot}38.\sin p$	$+0{\cdot}04.\sin(2p+220^\circ)$	$+0{\cdot}07.\sin(3p+287^\circ)$	$+0{\cdot}02.\sin(4p+172^\circ)$
Carrowkeel	Large tides.	$3{\cdot}35.\sin p$	$+0{\cdot}07.\sin(2p+238^\circ)$	$+0{\cdot}11.\sin(3p+205^\circ)$	
	Small tides.	$1{\cdot}95.\sin p$	$+0{\cdot}01.\sin(2p+319^\circ)$	$+0{\cdot}06.\sin(3p+199^\circ)$	$+0{\cdot}01.\sin(4p+152^\circ)$
Ballycastle	Large tides.	$1{\cdot}42.\sin p$	$+0{\cdot}07.\sin(2p+308^\circ)$	$+0{\cdot}07.\sin(3p+276^\circ)$	$+0{\cdot}03.\sin(4p+218^\circ)$
	Small tides.	$0{\cdot}88.\sin p$	$+0{\cdot}06.\sin(2p+338^\circ)$	$+0{\cdot}03.\sin(3p+311^\circ)$	$+0{\cdot}01.\sin(4p+293^\circ)$
Glenarm	Large tides.	$2{\cdot}89.\sin p$	$+0{\cdot}17.\sin(2p+76^\circ)$	$+0{\cdot}07.\sin(3p+227^\circ)$	$+0{\cdot}01.\sin(4p+310^\circ)$
	Small tides.	$2{\cdot}47.\sin p$	$+0{\cdot}05.\sin(2p+50^\circ)$	$+0{\cdot}04.\sin(3p+237^\circ)$	
Donaghadee	Large tides.	$5{\cdot}24.\sin p$	$+0{\cdot}07.\sin(2p+56^\circ)$	$+0{\cdot}03.\sin(3p+174^\circ)$	$+0{\cdot}01.\sin(4p+327^\circ)$
	Small tides.	$3{\cdot}96.\sin p$	$+0{\cdot}03.\sin(2p+318^\circ)$	$+0{\cdot}03.\sin(3p+230^\circ)$	$+0{\cdot}01.\sin(4p+85^\circ)$
Ardglass	Large tides.	$6{\cdot}90.\sin p$	$+0{\cdot}18.\sin(2p+98^\circ)$	$+0{\cdot}04.\sin(3p+145^\circ)$	$+0{\cdot}03.\sin(4p+125^\circ)$
	Small tides.	$4{\cdot}96.\sin p$	$+0{\cdot}07.\sin(2p+117^\circ)$	$+0{\cdot}04.\sin(3p+217^\circ)$	$+0{\cdot}03.\sin(4p+161^\circ)$
Clogher Head	Large tides.	$6{\cdot}79.\sin p$	$+0{\cdot}26.\sin(2p+109^\circ)$	$+0{\cdot}08.\sin(3p+166^\circ)$	$+0{\cdot}01.\sin(4p+233^\circ)$
	Small tides.	$4{\cdot}81.\sin p$	$+0{\cdot}13.\sin(2p+143^\circ)$	$+0{\cdot}07.\sin(3p+180^\circ)$	$+0{\cdot}02.\sin(4p+241^\circ)$
Kingstown	Large tides.	$5{\cdot}26.\sin p$	$+0{\cdot}38.\sin(2p+143^\circ)$	$+0{\cdot}02.\sin(3p+7^\circ)$	$+0{\cdot}02.\sin(4p+118^\circ)$
	Small tides.	$3{\cdot}69.\sin p$	$+0{\cdot}23.\sin(2p+165^\circ)$	$+0{\cdot}01.\sin(3p+225^\circ)$	$+0{\cdot}02.\sin(4p+171^\circ)$
Dunmore East	Large tides.	$5{\cdot}73.\sin p$	$+0{\cdot}14.\sin(2p+12^\circ)$	$+0{\cdot}15.\sin(3p+94^\circ)$	$+0{\cdot}01.\sin(4p+288^\circ)$
	Small tides.	$3{\cdot}91.\sin p$	$+0{\cdot}11.\sin(2p+3^\circ)$	$+0{\cdot}08.\sin(3p+103^\circ)$	$+0{\cdot}01.\sin(4p+198^\circ)$
New Ross	Large tides.	$6{\cdot}16.\sin p$	$+0{\cdot}47.\sin(2p+348^\circ)$	$+0{\cdot}26.\sin(3p+101^\circ)$	$+0{\cdot}03.\sin(4p+116^\circ)$
	Small tides.	$4{\cdot}51.\sin p$	$+0{\cdot}30.\sin(2p+346^\circ)$	$+0{\cdot}16.\sin(3p+95^\circ)$	$+0{\cdot}01.\sin(4p+63^\circ)$
Passage West	Large tides.	$5{\cdot}94.\sin p$	$+0{\cdot}29.\sin(2p+298^\circ)$	$+0{\cdot}09.\sin(3p+87^\circ)$	$+0{\cdot}04.\sin(4p+73^\circ)$
	Small tides.	$4{\cdot}19.\sin p$	$+0{\cdot}24.\sin(2p+316^\circ)$	$+0{\cdot}07.\sin(3p+95^\circ)$	$+0{\cdot}02.\sin(4p+43^\circ)$
Castle Townsend	Large tides.	$4{\cdot}79.\sin p$	$+0{\cdot}21.\sin(2p+297^\circ)$	$+0{\cdot}04.\sin(3p+259^\circ)$	$+0{\cdot}02.\sin(4p+331^\circ)$
	Small tides.	$3{\cdot}33.\sin p$	$+0{\cdot}16.\sin(2p+310^\circ)$	$+0{\cdot}03.\sin(3p+302^\circ)$	$+0{\cdot}03.\sin(4p+73^\circ)$

In order to institute a comparison of these numerical results with the formulæ given by theory, it may be convenient to premise the following expressions:—

If the tide were created in a uniform channel, forming a great circle round the earth, the expression for the height of the water would have the form

$$A.\sin p + B.\sin 2p + 90^\circ,$$

where B would have the same sign as A if the velocity of the tide-wave were greater than $\sqrt{\frac{gk}{4}}$, k being the depth of the channel.

If the tide at the mouth of a gulf be a pure tide, or one in which the elevation is expressed by $a.\sin p$, then the elevation at any point in the bay will be expressed by the formula

$$A.\sin p + B.\sin 2p + 90^\circ,$$

where (in the case of a gulf sufficiently long to have a tidal node) A and B have different signs from the mouth of the gulf to the node, and afterwards have similar signs.

If the tide at the mouth of an indefinitely long river be a pure tide, then the elevation at any point in the river will be expressed by the formula

$$A.\sin p + B.\sin 2p,$$

where B has the same sign as A if the section of the river be a parallelogram, but may have the opposite sign if the section expand very much at the top.

In all cases $\frac{B}{A}$ is a quantity of the same order as $\frac{\text{vertical oscillation of the water}}{\text{depth of the water}}$.

I shall now proceed to examine the results deducible from the last Table.

The stations Kilbaha, Caslch Bay, Old Head, Mallaghmore, may fairly be considered as littoral stations on the open Atlantic ocean. And their formulæ agree among themselves almost absolutely to the second term, and in a great measure to the third term. They show clearly that the Atlantic tide there is not a pure tide. But the form of the argument does not agree with either of the two first formulæ just cited, which alone can apply to it. At Castle Townsend, which is nearly as much exposed, but on a different side of the island, the formula agrees pretty well with the first of those above, supposing the depth of the sea very great.

At Dunmore East the tide has nearly assumed the form of a river tide.

Proceeding from Kingstown (where the character of the tide is similar to that at Kilbaha, &c.) to Clogher Head, Ardglass, and Donaghadee, the argument of the second term undergoes a progressive change, its phase being less advanced. As the epoch of the first term is absolutely the same at these stations (the tide being simultaneous at all of them), it appears that the wave represented by the second term is progressive. It seems therefore that it does not originate in the peculiarities of a gulf-tide (contained in the second formula just cited), but that it has been created either on the open sea or in the shallower water between Ireland and Cornwall, and now travels on as an independent wave.

From Mullaghmore to Port Rush, the second wave appears to travel with the same speed as the principal wave. In passing through the narrow channel to Glenarm, its phases appear to increase much more rapidly than those of the principal wave; or, it appears to travel more slowly, or in the opposite direction. This however is probably only an instance of the forced progression of the phases of wave in the channel connecting two tidal seas.

The general relations however of the waves depending on $2p$ at the different littoral stations will be seen more clearly from the following process:—Take the establishment of each station from Section XIII., and convert it into degrees at the rate of 1440° for a tidal day, and subtract the angle thus found from the angle added to $2p$. It is evident now that our phase p' at every station is referred to the same origin, namely to the time of the moon's transit at Greenwich. The expressions thus obtained for the quarto-diurnal waves are the following:—

Station.	Large tides.	Small tides.	Station.	Large tides.	Small tides.
	ft.	ft.		ft.	ft.
Kilbaha	$0{\cdot}16.\sin(2p'+244°)$	$0{\cdot}08.\sin(2p'+295°)$	Donaghadee ..	$0{\cdot}07.\sin(2p'+122°)$	$0{\cdot}03.\sin(2p'+41°)$
Casleh Bay ..	$0{\cdot}16.\sin(2p'+235°)$	$0{\cdot}07.\sin(2p'+296°)$	Ardglass.....	$0{\cdot}18.\sin(2p'+163°)$	$0{\cdot}07.\sin(2p'+199°)$
Galway	$0{\cdot}18.\sin(2p'+223°)$	$0{\cdot}08.\sin(2p'+277°)$	Clogher Head..	$0{\cdot}26.\sin(2p'+167°)$	$0{\cdot}13.\sin(2p'+218°)$
Old Head ..	$0{\cdot}08.\sin(2p'+208°)$	$0{\cdot}04.\sin(2p'+278°)$	Kingstown	$0{\cdot}38.\sin(2p'+195°)$	$0{\cdot}23.\sin(2p'+235°)$
Mullaghmore	$0{\cdot}06.\sin(2p'+198°)$	$0{\cdot}04.\sin(2p'+263°)$	Dunmore East .	$0{\cdot}14.\sin(2p'+72°)$	$0{\cdot}11.\sin(2p'+71°)$
Port Rush ..	$0{\cdot}08.\sin(2p'+113°)$	$0{\cdot}04.\sin(2p'+190°)$	Passage West..	$0{\cdot}29.\sin(2p'+344°)$	$0{\cdot}24.\sin(2p'+10°)$
Ballycastle ..	$0{\cdot}07.\sin(2p'+203°)$	$0{\cdot}06.\sin(2p'+245°)$	Castle Townsend	$0{\cdot}21.\sin(2p'+7°)$	$0{\cdot}16.\sin(2p'+27°)$
Glenarm	$0{\cdot}17.\sin(2p'+156°)$	$0{\cdot}05.\sin(2p'+147°)$			

The expressions for Courtown, the station intermediate between Kingstown and Dunmore East, are (as I remark by anticipation from the next section) intermediate between those for Kingstown and Dunmore East, but nearly coinciding with the former.

The variations in the values of the constants attached to $2p$ in the Table of page 113, seem to make it impossible for us to attribute this term to the local circumstances of each port, and the consideration of the Courtown tides in the next section will confirm this. The order of the numbers attached to $2p'$ in the last Table shows that it may be considered as a progressive wave, beginning at Kingstown nearly, and travelling both ways round the coast as far as Donaghadee. But whether such a thing is mechanically possible, or whether it can be true that the quarto-diurnal wave (which necessarily is created by the semidiurnal wave flowing over the shallower seas between Ireland and Cornwall) can show itself as a great swell opposite Kingstown, and can then be propagated even opposite to the semidiurnal wave and round the island, are points which I cannot explain.

On the whole, I am not able to pronounce with any confidence on the origin of this wave, but I have no doubt that, having been created, it travels along independently, and therefore that its existence is not due to the local circumstances of the several stations.

In regard to the river stations, I may remark that the Shannon does, in consequence of the barriers to the tide at Limerick, resemble a gulf in its tidal character; and the second of the formulæ above ought therefore to apply to it; and, as will easily be seen, it does apply with considerable approximation. The river Barrow, upon which New Ross is situated, is not obstructed in the same manner, and therefore we might expect the third formula to apply, and it does apply very nearly.

I omit discussion of the third and fourth terms, because theory, in a shape applicable to cases of nature, has not yet been extended sufficiently far. I may however observe that, as I have shown with regard to the tide at Deptford*, and to those at Southampton and Ipswich†, so also at Limerick, and in some measure at Foynes Island and New Ross, the third term is almost as important as the second, and the fourth is one of considerable magnitude.

I may also call the attention of the wave-theorist to this circumstance, that the difference between the coefficients for large tides and for small tides does not appear sufficiently great in relation to the difference between the coefficients of the first term for large tides and small tides. The coefficient of the first term being considered as of the first order, that of the second term would consist of a series whose leading term was of the second order, &c. The departure from the proportions given by this consideration may depend upon the succeeding terms of the series.

It is also to be remarked that there is an undoubted difference between the arguments for large tides and for small tides. This seems to show that each sine is accompanied by a cosine, and that their coefficients have, for their leading terms, terms of different orders in respect of the first coefficient of semi-range.

Section XVII.—*Separate discussion of the tidal observations made at Courtown.*

The observers at Courtown soon discovered that it was impossible to adhere to the instructions sketched in Section I. The tide was sometimes apparent as a semidiurnal tide, but with considerable irregularity; at other times, the character of semidiurnal tide was (to common observation) completely lost, and in its stead there was a small tide four times a day; in all cases the tide was small. In this state of things, the course which they adopted was, to observe continuously whenever the semidiurnal tide was not distinctly marked, and to follow the usual rule (with some extension of observations) when it was well-marked. In this manner a tolerably complete and very important set of observations has been secured. In several cases the observations have been interrupted by the discharge of water from the sluices for scouring the harbour of Courtown; in some instances there has been no difficulty in filling up the observations by conjecture, in others I have been obliged to adopt the limits of the tide (in the form of analysis) to these interruptions.

In order to apply the method of analysis explained in Section X., it was necessary to fix upon precise limits for each tide. But as no limits could be obtained at Cour-

* Philosophical Transactions, 1842, p. 4. † Ibid. 1843, pp. 49 and 53.

town (as at other stations) from the observations themselves, it was necessary to take them from another station. The station selected for this purpose was Ardglass. The limits and the divisions into twelfths and sixteenths for Ardglass were therefore adopted for Courtown, as far as the continuity of observations permitted. Where (as is just mentioned) it was necessary to change the limits, this was done if possible by altering the limits and all the divisions by three or six of the twelfths (corresponding to four or eight of the sixteenths); in other cases they were all altered by a definite time. Then the means of the heights in these observations were treated in the usual way.

A correction for diurnal tide was indispensable (the diurnal tide being, at some times, as large as the semidiurnal). For obtaining this from the observations there were two means. One was, by means of the investigations connected with tertio-diurnal tide to be detailed in the next section. These gave the diurnal tide for the beginning and the fourth parts of each of the whole day's group used there. These were the diurnal coefficients proper to be used in the semidiurnal groups composing each day's group. But the corresponding diurnal coefficient applicable at the times of any Ardglass high or low water was easily deduced from them by taking the sum of the products of the coefficients next it by the cosines of their respective distances from it (considering 360° as corresponding to a tidal day). Another method was, to select from the observed heights those which corresponded to the times of Ardglass high water and Ardglass low water, and to treat them by the method of fourth differences explained in Section III.; as these heights ought (in relation to each other) to be perfectly free from the effect of semidiurnal tide and of all tides occurring at portions of a semidiurnal tide. Using then these two methods, and adopting the mean of their results when both could be applied, a number of diurnal coefficients were obtained from the observations themselves. On comparing these with the diurnal coefficients at the neighbouring stations, it was found that the coefficients at Courtown might very well be represented by the mean of those for Kingstown and Dunmore East at the same time. Accordingly, for all the times for which no diurnal tide could be safely extracted from the observations, the mean of coefficients for Kingstown and Dunmore East was used; and from these, when necessary, the coefficients for other times were deduced by the operation described above. The process then pursued was exactly the same as in other cases, except that no correction was attempted for rise of water. The results are the following, which differ in form from preceding results only in this circumstance, that the origin of phase is the time of mean water at Ardglass preceding high water, and that therefore an angle expressed by a number of degrees must be added to the phase to form the argument of the first variable term.

Height of the water in each individual tide at Courtown, excluding diurnal tide, where the origin of p is at the same time as at Ardglass (p. 82 and 83),

Analysed time of high water, corresponding to $p+\epsilon_0=90$.	A_p.	C_1.	ϵ_1.	C_2.	ϵ_2.	C_3.	ϵ_3.	C_4.	ϵ_4.
1842. h m	ft.	ft.	°	ft.	°	ft.	°	ft.	°
June 22. 20 13	16·93	0·74	109	0·43	176	0·03	320	0·02	103
23. 8 30									
23. 20 46	17·30	0·74	91	0·36	133	0·05	93	0·02	265
24. 9 25									
24. 22 4	17·55	0·50	73	0·36	102	0·04	180	0·04	29
25. 10 11									
25. 22 18	17·03	0·78	83	0·33	127	0·08	253	0·05	337
26. 10 13									
26. 22 9	16·55	0·46	107	0·33	122	0·03	178	0·04	200
27. 10 21									
27. 22 5	16·58	0·38	125	0·29	128	0·04	160	0·04	152
28. 10 30									
28. 22 39	16·66	0·17	133	0·22	130	0·03	238	0·03	298
29. 11 24	16·64	0·25	112	0·05	130	0·05	106	0·01	217
29. 22 42	16·71	0·17	199	0·24	130	0·03	275	0·02	314
30. 9 29	16·59	0·18	199	0·28	148	0·03	164	0·03	60
30. 21 3	16·69	0·36	251	0·19	126	0·02	59	0·03	237
July 1. 8 50	16·65	0·23	239	0·19	138	0·04	164	0·04	227
1. 21 14	16·66	0·28	256	0·23	128	0·03	280	0·03	333
2. 9 21									
2. 16 7	16·88	0·09	58	0·18	83	0·03	296	0·05	137
3. 4 42									
3. 17 26									
4. 5 51	17·59	0·13	51	0·15	106	0·04	127	0·05	200
4. 22 34									
5. 11 4	17·40	0·12	291	0·21	143	0·12	114	0·04	358
5. 18 38									
6. 7 8	16·32	0·51	74	0·29	134	0·05	50	0·04	350
6. 19 52									
7. 8 12	17·21	0·37	63	0·52	120	0·11	207	0·05	43
.....	....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....	....
8. 20 42									
9. 9 12	16·65	1·29	81	0·44	132	0·10	138	0·05	260
9. 21 32	16·62	1·37	82	0·37	134	0·11	87	0·07	231
10. 9 58									
10. 22 25	17·62	1·18	77	0·16	96	0·09	101	0·08	66
11. 10 40									
11. 22 56	16·48	1·26	82	0·34	116	0·10	100	0·06	202
12. 11 24									
12. 23 51	16·59	0·93	86	0·42	127	0·01	1	0·03	199
(13. 9 59)	....	....	....	....	....	....	....	....	....
(13. 20 7)	....	....	....	....	....	....	....	....	....
(14. 6 15)	....	....	....	....	....	....	....	....	....
(14. 16 23)	....	....	....	....	....	....	....	....	....
15. 2 31	16·08	0·27	58	0·43	121	0·04	282	0·07	345
15. 17 56	16·58	0·04	339	0·24	136	0·06	329	0·02	192
16. 6 26									
16. 20 45	17·05	0·26	288	0·33	106	0·08	101	0·11	178
17. 9 36	17·11	0·09	278	0·15	150	0·11	328	0·10	358
17. 22 4	16·89	0·10	283	0·38	135	0·01	160	0·03	164
18. 2 39									
18. 15 45	16·90	0·01	155	0·35	115	0·17	106	0·08	231
19. 5 18	16·81	0·18	130	0·37	142	0·10	40	0·12	113
19. 19 5	16·82	0·17	93	0·29	115	0·16	304	0·06	304
20. 7 58	16·70	0·21	53	0·35	125	0·14	122	0·10	131
20. 19 41	16·80	0·58	68	0·22	151	0·04	294	0·03	341
21. 7 35	16·61	0·57	93	0·36	138	0·05	169	0·05	233
21. 20 2									
22. 8 22	16·47	0·74	91	0·28	141	0·04	131	0·01	12

expressed by the formula $A_0+C_1\sin(p+c_1)+C_2\sin(2p+c_2)+C_3\sin(3p+c_3)+C_4\sin(4p+c_4)$, and p increases by 360° during one complete tide at Ardglass.

Analysed time of high water, corresponding to $p+c_1=90°$.	A_0.	C_1.	c_1.	C_2.	c_2.	C_3.	c_3.	C_4.	c_4.
1842. h m	ft.	ft.	°	ft.	°	ft.	°	ft.	°
July 22. 20 40	16·32	0·80	89	0·34	135	0·05	152	0·01	158
23. 8 54									
23. 21 9	16·32	0·89	96	0·37	145	0·06	79	0·07	158
24. 9 18									
24. 21 28	16·51	0·74	103	0·23	125	0·12	211	0·05	198
25. 9 41									
25. 21 54									
26. 10 17	16·37	0·73	105	0·35	128	0·07	248	0·02	270
26. 22 25	16·36	0·80	102	0·21	155	0·12	106	0·02	75
27. 10 35	16·41	0·60	111	0·27	124	0·06	168	....	....
27. 23 13	16·34	0·61	106	0·25	129	0·04	130	....	....
28. 11 7	16·42	0·39	108	0·30	117	0·04	155	0·03	341
28. 22 37	16·37	0·35	109	0·10	127	0·06	171	0·04	161
29. 10 2	16·44	0·32	158	0·23	128	0·07	148	0·01	222
29. 21 25	16·36	0·24	163	0·22	132	0·04	254	0·05	341
30. 8 42	16·38	0·25	208	0·24	109	0·02	61	0·03	43
30. 20 35	16·31	0·25	233	0·24	134	0·05	10	0·05	9
31. 8 38	16·25	0·41	247	0·18	116	0·01	105	0·03	245
31. 20 55	16·21	0·43	259	0·19	150	0·01	249	0·02	18
August 1. 9 8	16·37	0·48	266	0·27	118	0·02	87	0·02	107
1. 21 6	16·53	0·34	287	0·21	148	0·02	46	0·02	36
2. 9 20	16·57	0·36	305	0·25	149	0·01	226	0·02	78
2. 19 45	16·42	0·09	9	0·26	150	0·05	30	0·03	122
3. 7 36	16·32	0·22	31	0·31	159	0·02	63	0·02	39
3. 18 27	16·48	0·35	83	0·20	148	0·06	110	0·03	177
4. 6 44	16·47	0·60	82	0·26	170	0·09	45	0·09	131
4. 19 17	16·76	0·88	79	0·35	152	0·04	274	0·07	27
5. 8 1	16·73	1·13	69	0·41	156	0·04	216	0·05	80
5. 20 0	16·58	1·23	80	0·33	140	0·09	53	0·08	55
6. 8 18									
6. 20 36	16·65	1·53	78	0·41	110	0·11	128	0·05	3
7. 9 5									
7. 21 34	16·46	1·89	75	0·45	141	0·03	169	0·06	127
8. 9 56									
8. 22 18	16·64	1·70	74	0·52	127	0·07	118	0·01	225
9. 10 4									
9. 21 50	17·31	1·60	114	0·28	225	0·21	48	0·09	226
10. 10 45									
10. 23 40	16·56	1·32	82	0·33	127	0·11	269	0·09	215
11. 11 57									
12. 0 14	16·62	0·59	88	0·41	142	0·02	329	0·03	141
12. 13 15	16·63	0·58	72	0·22	120	0·05	222	0·03	59
12. 23 49	16·26	0·09	125	0·29	120	0·06	356	....	....
13. 9 26									
13. 20 54	16·29	0·11	209	0·31	123	0·11	29	0·01	247
14. 8 41	16·20	0·25	274	0·27	117	0·07	88	0·11	187
14. 21 8	16·29	0·34	260	0·39	150	0·05	354	0·01	216
15. 9 33	16·32	0·34	287	0·35	126	0·06	243	0·03	235
15. 21 50	16·35	0·39	277	0·21	130	0·04	27	0·02	208
16. 10 6	16·55	0·13	307	0·17	148	0·03	157	0·02	350
16. 22 56	16·31	0·25	300	0·24	113	0·08	94	0·05	178
17. 6 30	16·78	0·21	78	0·14	122	0·05	169	0·02	47
17. 18 41	16·58	0·19	84	0·28	120	0·07	250	0·08	325
18. 7 24									
18. 20 7	17·07	0·17	64	0·30	122	0·05	76	0·04	90
.....	....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....	....
.....	....	....	....	....	....	....	....	....	....
20. 20 20	16·57	0·92	89	0·23	123	0·04	124	0·02	267

Upon inspecting the numbers in the column headed c_1, it will be perfectly evident that there is an error on August 9. The semidiurnal tide on that day is (comparatively) large, its whole range exceeding three feet; and there is no instance throughout all the observations of an irregularity equal to that which corresponds to an anomaly of 30° with that range. I have no doubt that all the observations are recorded too early by one hour, an error which would easily be committed at beginning, and which, where the observations are entered on forms ready prepared, would be retained to the end. Correcting on this supposition, the three successive times of high water would be August $9^d\ 10^h\ 34^m$, August $9^d\ 22^h\ 50^m$, and August $10^d\ 11^h\ 15^m$; and the values of c_1, c_2, c_3, c_4, for August $9^d\ 22^h\ 50^m$ would be nearly 84°, 165°, 218°, and 106°.

Next I would remark that there is undoubtedly an error of the same kind in the tide of July 4–5; but as the tide is then very small, I have not ventured to state precisely the alteration which I would propose.

Thirdly, observing that where the tide is very small, the hours on successive days occur earlier, in each of the instances where the order is well-marked (as from June 27 to July 3, from July 27 to July 31, and from August 12 to August 14), there can be no doubt that the same thing must hold during the interruption of observations about July 13 and 14; and thus it will be seen that there are certainly four high waters lost at that time. I have inserted four numbers by simple interpolation, to show, within two or three hours, the times of the lost high waters.

It is also to be remembered that nothing can be inferred from such tides as those of July 15–16 and July 18, where the coefficients are 0·04 and 0·01.

Bearing these remarks in mind, and giving particular attention to the second half of the observations, which, both for the regularity of the system pursued by the observers and for the agreement of the results, is greatly superior to the first, we arrive at the following conclusions:—

The angle c_1 increases continually, and its increase amounts to 360° in about fourteen days. When its value is not far from 360°, its increase is extremely rapid. One of these jumps occurs between August $2^d\ 9^h$ and August $2^d\ 19^h$, and one between August $16^d\ 22^h$ and August $17^d\ 6^h$; one also between July $2^d\ 9^h$ and July $2^d\ 16^h$; another takes place between July $17^d\ 22^h$ and July $19^d\ 5^h$, but (the results being at that time somewhat irregular) the time cannot be precisely pointed out. It is evident from this that the Courtown tides are more numerous than the Ardglass tides by one tide in fourteen days nearly.

The mean solar time of high water does not increase constantly as at other stations, but oscillates backwards and forwards. Thus, from July 19 to August 18 (in which period the tides at other stations have gradually retarded by twenty-four hours), the evening tides always occur between $5^h\ 18^m$ and $13^h\ 15^m$, and the morning tides always occur between $18^h\ 27^m$ and $24^h\ 14^m$, each time having twice oscillated between its extreme limits in that period.

From these circumstances it is plain that the time of high water (confining our remarks to the term $C_1 \sin(p+c_1)$) respects mainly the time of the sun's transit and not that of the moon's transit; and therefore, at Courtown, *the solar tide is greater than the lunar tide*. This is, I believe, the only place on the earth in which such a result has been distinctly obtained. The observations of Sir EDWARD BELCHER* show that at Otaheite the solar tide is as nearly as possible equal to the lunar tide.

The times following lunar syzygy by two days were June 24, 9^h, July 9, 19^h, July 23, 23^h, August 8, 4^h, August 22, 16^h; and about these times the luni-solar tide is greatest at all the other stations. About these times also the soli-lunar tide at Courtown is greatest.

The solar hour of high water at Kingstown, at the highest tides, is about $12^h\ 30^m$, that at Dunmore East is about $6^h\ 40^m$. These are the two stations nearest to Courtown on the north and south sides. The solar hour of high water at Courtown at the same times is about $9^h\ 30^m$. At these times the effects of the sun and the moon are simultaneous as to phase, so that we may treat the result as if there were only a single wave. It would seem then that the transition from a tide of elevation at Dunmore East to one of simultaneous depression at Kingstown, and *vice versâ*, is not effected entirely by a node dividing the elevated wave from the depressed wave. It appears that there is also a small progressive wave. The geometrical representation appears to be this; that there is a large stationary wave, having a node near Courtown, and making high water simultaneous in all parts of the inland sea or Irish Sea, and synchronic with low water in the exterior sea; and that there is mingled with it a very small progressive wave. As to the mechanical explanation of it, I can offer nothing positive. But I would suggest for the consideration of wave-theorists, whether, in the case of a gulf (as the Irish Sea) having a small outlet (like the North Channel), it be possible that the fluctuation may be represented correctly on mechanical principles by a combination of the stationary wave peculiar to a gulf with the progressive wave peculiar to the channel.

Returning now to the consideration of the magnitude of the tide, it is evident that the coefficient of the lunar tide has been diminished in a far greater degree than that of the solar tide. There is one explanation of this which is very plausible, and which I have no doubt is the true one, namely that the node for the lunar tide and the node for the solar tide do not coincide (which, on account of the difference of the periods of these tides, we should expect *à priori*), and that the node for the lunar tide is much nearer to Courtown than is the node for the solar tide. It is clearly possible that, by varying our choice of stations, we might vary the proportion of the two effects in any degree whatever. Nay, by choosing a station between the two nodes, we might have the solar and lunar effects to conspire when they are opposed at other places, and *vice versâ*; and thus a station would be found where the spring tides occur at the same time as neap tides at other places. This does not occur at

* Philosophical Transactions, 1843, p. 55, &c.

Courtown; but the reader, in reflecting on this, will see the importance of our comparison of the time of the largest tides at Courtown with the time of the largest tides at the other stations.

We shall now proceed to examine the second periodical term; which will be found not less remarkable than the first.

On glancing over the values of c_2 (first correcting that on August 9 as I have suggested), the reader cannot fail to be struck with the general uniformity of the numbers. It is quite evident that this term has no respect to the sun's transit, but that it respects only the moon's transit, or the commencement of the luni-solar tide. If we look also to the coefficient C_1, we find that its magnitude is considerable, sometimes exceeding that of the first term. It is clear therefore that this term does not originate as a derivative from the first term, produced by the local circumstances of the port. It does not change greatly, but nevertheless has on the whole larger values about the times of large tides than about the times of small tides. If we divide the observations into two groups, one corresponding to large tides and the other to small tides (the limits being the same as those for the other stations); and if we correct as before for the establishment at Ardglass (to which station the Courtown tides have been referred); and if we collect the expressions for the second periodic term at the three stations, Dunmore East, Courtown and Kingstown; we have this sequence of expressions.

	Kingstown.	Courtown.	Dunmore East.
Large tides	ft. $0{\cdot}38 \cdot \sin(2p' + 195^\circ)$	ft. $0{\cdot}35 \cdot \sin(2p' + 196^\circ)$	ft. $0{\cdot}14 \cdot \sin(2p' + 72^\circ)$
Small tides.....	$0{\cdot}23 \cdot \sin(2p' + 235)$	$0{\cdot}26 \cdot \sin(2p' + 202)$	$0{\cdot}11 \cdot \sin(2p' + 71)$

It appears here quite evident that this term at Courtown is only the representation of the same quarto-diurnal tide which shows itself along the whole coast. This wave (whatever its origin may be) appears to have its greatest range and its beginning of phases at Kingstown, and to spread both ways, diminishing in range as it goes.

The succeeding terms at Courtown are insignificant.

We have now a clear representation of the apparently confused phenomena of the tides at Courtown. Both the semidiurnal tides are very much diminished, the lunar so much that its range is rather less than that of the solar tide. The quarto-diurnal tide exists in nearly its greatest magnitude. The geometrical representation is perfect; the mechanical explanation is not complete. In both respects, as regards what is reduced to law and what is yet incomplete, the Courtown tides must be regarded as the most remarkable that have ever been examined.

Section XVIII.—*Examination into the question of tertio-diurnal tide.*

The observations at Courtown, as has been mentioned, and as appears from the Table in pages 118 and 119, were continued without interruption, day and night, for

a considerable time. The observations at Dunmore East, as appears from the beginning of the Table in page 88, were also continued without interruption for several days. These circumstances appeared to me to offer a convenient opportunity of examining whether the tide occurring three times in the lunar day, which is pointed out by theory, is sensible in the seas around Ireland.

The calculations for this purpose were made in the same manner as the other calculations described in Section X. The means for the twelfth parts of semidiurnal tide, or for the twenty-fourth parts of diurnal tide, having been already found for the operations in Section X., the means of the first and second, of the third and fourth, of the fifth and sixth, &c. were taken; and these were evidently the same as the means for the twelfth parts of diurnal tide. They were then treated by the use of the printed skeleton form shown in Section X., in the same manner as the means for the twelfth parts of semidiurnal tide. Thus the diurnal tide and tertio-diurnal tide were obtained; and a consideration of the principles on which that process is founded will show that the result is in no way affected by the semidiurnal or quarto-diurnal tide. The constants additive to the phase, at Courtown, were corrected where necessary to adapt them to the supposition that the phases are measured from the mean water preceding High Water, First Division, at Ardglass; those at Dunmore East are referred to the same state of tide at Dunmore East. The angle p in the following Table increases by 360° in a tidal day. The day which is set down is that whose astronomical commencement occurs in the tidal day (the limits of the tidal day will be seen in Section X.).

Courtown.			Dunmore East.		
Day.	Diurnal tide.	Tertio-diurnal tide.	Day.	Diurnal tide.	Tertio-diurnal tide.
	ft.	ft.		ft.	ft.
June 29.	$0{\cdot}57 \cdot \sin(p+250^\circ)$	$0{\cdot}08 \cdot \sin(3p+188^\circ)$	June 24.	$0{\cdot}33 \cdot \sin(p+208^\circ)$	$0{\cdot}16 \cdot \sin(3p+253^\circ)$
30.	$0{\cdot}31 \cdot \sin(p+253)$	$0{\cdot}04 \cdot \sin(3p+86)$	25.	$0{\cdot}35 \cdot \sin(p+207)$	$0{\cdot}08 \cdot \sin(3p+304)$
July 1.	$0{\cdot}43 \cdot \sin(p+264)$	$0{\cdot}02 \cdot \sin(3p+177)$	26.	$0{\cdot}20 \cdot \sin(p+192)$	$0{\cdot}11 \cdot \sin(3p+220)$
17.	$0{\cdot}20 \cdot \sin(p+350)$	$0{\cdot}14 \cdot \sin(3p+207)$	27.	$0{\cdot}27 \cdot \sin(p+170)$	$0{\cdot}10 \cdot \sin(3p+210)$
18.	$0{\cdot}05 \cdot \sin(p+201)$	$0{\cdot}06 \cdot \sin(3p+236)$	28.	$0{\cdot}33 \cdot \sin(p+161)$	$0{\cdot}09 \cdot \sin(3p+182)$
19.	$0{\cdot}24 \cdot \sin(p+265)$	$0{\cdot}05 \cdot \sin(3p+279)$	29.	$0{\cdot}32 \cdot \sin(p+150)$	0·00
20.	$0{\cdot}36 \cdot \sin(p+261)$	$0{\cdot}23 \cdot \sin(3p+187)$	July 1.	$0{\cdot}19 \cdot \sin(p+187)$	$0{\cdot}07 \cdot \sin(3p+349)$
26.	$0{\cdot}38 \cdot \sin(p+256)$	$0{\cdot}06 \cdot \sin(3p+179)$	2.	$0{\cdot}17 \cdot \sin(p+178)$	$0{\cdot}03 \cdot \sin(3p+99)$
27.	$0{\cdot}43 \cdot \sin(p+253)$	$0{\cdot}05 \cdot \sin(3p+132)$			
28.	$0{\cdot}49 \cdot \sin(p+240)$	$0{\cdot}06 \cdot \sin(3p+158)$			
29.	$0{\cdot}29 \cdot \sin(p+248)$	$0{\cdot}08 \cdot \sin(3p+84)$			
30.	$0{\cdot}25 \cdot \sin(p+276)$	$0{\cdot}08 \cdot \sin(3p+87)$			
31.	$0{\cdot}15 \cdot \sin(p+287)$	$0{\cdot}10 \cdot \sin(3p+98)$			
Aug. 2.	$0{\cdot}16 \cdot \sin(p+10)$	$0{\cdot}01 \cdot \sin(3p+306)$			
3.	$0{\cdot}10 \cdot \sin(p+105)$	$0{\cdot}08 \cdot \sin(3p+315)$			
4.	$0{\cdot}38 \cdot \sin(p+106)$	$0{\cdot}02 \cdot \sin(3p+3)$			
5.	$0{\cdot}53 \cdot \sin(p+87)$	$0{\cdot}11 \cdot \sin(3p+328)$			
12.	$0{\cdot}34 \cdot \sin(p+57)$	$0{\cdot}12 \cdot \sin(3p+346)$			
13.	$0{\cdot}11 \cdot \sin(p+357)$	$0{\cdot}07 \cdot \sin(3p+238)$			
14.	$0{\cdot}09 \cdot \sin(p+46)$	$0{\cdot}11 \cdot \sin(3p+211)$			
15.	$0{\cdot}05 \cdot \sin(p+286)$	$0{\cdot}07 \cdot \sin(3p+264)$			
16.	$0{\cdot}26 \cdot \sin(p+286)$	$0{\cdot}04 \cdot \sin(3p+70)$			

The diurnal tide is here shown pretty well, and the times of its changes of sign agree well with those found in Section III. But the numbers for tertio-diurnal tide appear to me perfectly lawless. I think that they must be regarded as principally the effects of accident.

On the whole, I am inclined to believe that, as far as evidence goes, the tertio-diurnal tide is not sensible on the coast of Ireland.

II. *On the Temperature of the Springs, Wells and Rivers of India and Egypt, and of the Sea and Table-lands within the Tropics.* By *Captain* Newbold, *Madras Army, F.R.S.*

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Professor Jameson, in his chapter on the hydrography of India, justly remarks, "Although India, like other great tracts of country, contains many springs, these have hitherto attracted but little attention. The temperature of but few of them is known; their magnitudes and geognostical situations are scarcely ever mentioned; and their chemical composition, excepting in a very few instances, has been neglected. The most important feature in the natural history of *common* or *perennial* springs, namely their temperature, is rarely noticed, although a knowledge of this fact is illustrative, not only of the mean temperature of the climate, but also of the elevations of the land above the level of the sea; and our information in regard to their chemical nature is equally meagre†." Since the publication of these remarks, much has been done by Prinsep and others in these branches of Indian hydrography, but more remains to be effected before this reproach can be wiped out. The heat of springs having a temperature little above the mean of that of the surrounding country has been rarely noticed, though I feel convinced many such exist in India. That of springs of high temperature, more attractive to the casual observer, has been more remarked.

My own observations, and the few inferences I have ventured to draw from some of them, are not offered as sufficient data for the establishment of laws, but merely as a contributory mite to knowledge; in the view of courting inquiry and observation by others more competent and better situated for continued research than myself. The thermometric observations have been snatched generally on the line of march, or during hasty travel: since my return to England, through the kindness of Mr. Roberton, they have been adjusted to the indications given by the standard thermometer of the Royal Society.

The observations extend at irregular intervals from Alexandria to Malacca, or from 31° 13′ of north latitude to within 2° 14′ north from the equator; and between the meridians of 27° and 103° of east longitude. I had continued those on the temperature of the sea as far as the Bosphorus and Black Sea, but have judged them

* This paper having unfortunately been mislaid after its receipt by the late Assistant Secretary, the reading of it was thus necessarily delayed.—S.H.C.

† Ed. Cab. Cyc. No. 8. p. 287.

superfluous in a paper limited almost to the subject of intertropical temperature.

In the columns of the registers, the latitude and longitude, the approximate height above the sea, the nature of the surrounding formation, the depth to the surface of the water and depth of water, the temperature of the air, the month during which each observation was taken, and the approximate annual mean of the climate in which the wells, &c. occur, are specified as far as practicable. In the column of remarks will be found a few observations on the chemical nature of the water, and on the size of the wells and springs*. Those were selected which contained water all the year round; though all were, more or less, subject to fluctuation during the wet and dry seasons. The wells in Egypt differ from the "*bouries*" of India in being less open and exposed to atmospheric influence. Those in the valley of the Nile are mere shafts sunk through the black alluvium to an impervious marly and sandy bed, to depths varying, according to the distance from the river, from ten to forty feet. Their circumferences, like those of the Indian "pot wells," are from nine to twelve yards. They mainly depend on the river for water, which is supplied by infiltration through the soil,—a circumstance to be taken into consideration in all indications afforded of their temperature. The wells in the deserts of Egypt, like those of Ajmír and the western deserts of India, are frequently of great depth, lying under strata of sand, gravel, and a calcareous sandstone, on an argillaceous or marly bed, sometimes at a depth of 300 feet below the surface of the surrounding country. In the granitic districts of Upper Egypt, in the Thebaid desert, however, I have observed springs rising through the almost vertical strata to the surface.

In India, most of the wells marked as occurring in granite, trap, limestone and sandstone, result from springs, and are consequently not so much influenced in temperature by the monsoon rains as those in lateritic rocks, which, from their porous structure, admit of the percolation of rain water to a considerable extent.

The temperature was generally taken at about 10 A.M., a time when I found it to approximate nearest the diurnal mean; and, whenever practicable, at the depth of about ten feet from the surface.

The following are the general results of many hundred observations:—

1st. In low latitudes the temperature of the deepest wells and springs is a little higher than the mean temperature of the air. Exceptions occur: for example, the temperature of a deep well at Gádigánúr, on the banks of the Toombuddra, between the 15th and 16th parallels of north latitude, at an elevation of about 1200 feet from the sea, was so low as 72°·5 (the temperature of the air in the shade, at the time of observation, 80°·5), while that of the springs and river in the vicinity was from 77° to 79°·5. Ranges of hills, attaining an altitude of 1500 feet above the plain, rose at no great distance; a circumstance suggesting the probability that the cold spring had its

* The observations of others will be denoted in the column of remarks by the names of the observers. The scale throughout is that of FAHRENHEIT.

source at an elevation having a mean temperature lower than that of the plain where the water appears on the surface.

2nd. The temperature of strongly saline and sulphureous springs is, on the average, higher than those of pure water.

3rd. Both saline and cold springs are seen to occur within a few feet from thermal and freshwater springs; a fact to be ascribed probably to their rising through different seams of the subjacent strata (often highly inclined), and to the different depths and heights from which the supply of water is derived.

4th. The temperature of wells, particularly those with a small area, much used for purposes of irrigation, is thereby artificially increased.

5th. The temperature of shallow exposed wells, springs and rivers, especially such as have sandy beds, is subject to great diurnal fluctuation, conforming, though to a less extent, to that of the superincumbent atmosphere. The surface water of deep wells partakes of this fluctuation, to a depth varying according to the transparency of the water, extent of surface, degree of exposure, and clearness of the sky. In muddy water the surface is heated to a greater extent, but a foot or two deep is less affected by the calorific action of the solar rays than clear water.

The transparent water of a large well at Bellary, lat. 15° 5′ N. and long. 76° 59′ E., situate on a table-land elevated 1600 feet above the sea's level, and containing sixteen feet of water, I found, at the depth of nine feet from the surface, to vary but one degree during the day, from sunrise to sunset, and this in several hundred experiments. The minimum, 79°·5, took place a little after sunrise, and the maximum, 80°·5, at 3 P.M. following those of the air. The diurnal variation of the water an inch below the surface amounted to 12°. During the commencement of the dry weather, as the heat increased, the water gradually decreased, and the diurnal fluctuations became greater, and increased at a greater rate than that of the decrease of the water.

Thermal Springs.—The thermal springs, both of India, the peninsula of Sinai and Egypt, are, with few exceptions, either mineral or gaseous. Those near the shores of the Red Sea are sulphureous; and strictly speaking, perhaps, should not be classed as thermal springs, from the great probability of their being connected with the volcanic belt that passes under the bed of the Red Sea, and bursting up from its watery fetters appears in the semi-dormant volcano of Gebel Teer, and in the lavas of Aden, beyond the straits of Babel-Mandel. The highest known temperature of the thermal springs is 102°, viz. that of El Kasr in the Oasis of Dakhleh; in the peninsula of Sinai, 91°6, that of the Hummám Músa, hot-baths of Moses (Wells of Elim?) near Tor. It is probable, from reports given me by the Arabs, that the Hummám Pharáon, hot-baths of Pharaoh, about eighty-five miles northerly from Tor, are of higher temperature. The maximum attained by the thermal springs of India is 194° at Jumnotri in North Hindostan (lat. 30° 52′ N.); a temperature almost equivalent, at that elevation—10849 feet above the sea's level—to the boiling point of water, and 18° higher than that of the hottest known thermal spring of Europe unconnected with present active vol-

canos, namely, 176° Fahr., that of Chaudes Aigues in Auvergne. The temperature of the hottest known thermal spring in the world, according to M. Arago, is that of Las Trincheras in Venezuela, stated, on the authority of Humboldt and Boussingault, to have increased 11° since 1806 to February 1823, viz. from 195° to 206° Fahr. Had M. Arago stated its elevation above the sea, a better comparison between its temperature and that of Jumnotri might have been formed. It would be interesting to observe whether any similar increment of heat takes place in the chain of thermal springs that rise abundantly along the great line of dislocation at the southern base of the Himálaya chain, or whether the temperature falls, as in some thermal springs among the East Pyrenees. It is certain that the majority of the springs strictly termed thermal, occur in India at or near lines of great faults occasioned by the upheaving of plutonic rocks, a fact that speaks intelligibly as to the great depth at which the earth's crust has been broken up.

Hot springs were found by Burnes in the salt districts of the Punjaub. In Thibet, M. Csoma de Koros mentions the occurrence of hot springs between U and Ts'ang. They are numerous in the mountains lying east from the Ma-p'-ham lake, especially at one place, where there is a hole out of which vapour continually issues, and at certain intervals, as in Iceland, hot water is ejected with great noise to the height of twelve feet. The water of the hot springs of Assam was found by Mr. J. Prinsep to contain bitumen and sulphuretted hydrogen. One held in solution a portion of muriate of soda. Many other warm springs are known to occur, besides those mentioned in the register, regarding the temperature and chemical composition of which further information is desirable. For instance, those of Hummám Pharáon on the east shore of the Red Sea; of Vizrabhaee, forty-eight miles north of Bombay; at Mohr on the Bancoot river, about seventy-five miles south of Bombay; of Soonup Deo, and Oonup Deo among the Satpoora hills in Khandésh; of Rishí-kúnda in Rajmahal; of Muktinath and Bhadrinath in North Hindustan; of Tooee, near Ruttenpore on the Mhye river, in Guzerat; of Lawsoondra, eighteen miles W.N.W. from Tooee; of Uteer, about thirty miles from Poorea near Korachi, on the Indus; of the diamond district at Punnah, in Bundelcund; of Oetha-gur, and Bannassa, near the sources of the Jumna; of the rivulet of Loland Khad near the Sutledge; of those near the confluence of the Soar and Elgie rivers with the Ganges; of many known to exist in the Birman empire and Malayan peninsula, and of Bhotan. The last-mentioned springs throw up spheroids of silex, which are brought to Almorah and there sold by the native merchants for duck shot*. These spheroids resemble those of the springs of Carlsbad in Bohemia, and of the Geysers. The silex composing them has doubtless been held in solution by the water; but it remains yet to be shown whether it contains, or not, that peculiar combination of silica and soda, which, according to Mr. Faraday, characterizes the water of the Geysers†; a combination ceasing to exist when the water is evaporated: the silica being then de-

* M'Lelland.

† Barrow's Visit to Iceland, pp. 209, 211.

posited in an insoluble condition, while the alkali, probably by the agency of the carbonic acid of the atmosphere, is set free, and remains dissolved in the water in considerable quantity. In Southern India many thermal springs, hitherto entirely unnoticed, are suspected to occur; Colonel Sykes states that he has been informed of their existence in Canara: I have heard of one among the Raidrúg hills in the Ceded districts,—in the Koondahs on the west coast,—and discovered another at the base of the hills south of Cuddapah having a temperature of 88°, as noted in the register. A spring near Salem in South India is probably thermal, having a temperature of 84°, ascertained for me by Mr. G. Fischer.

Temperature of Rivers.—The supposition that the temperature of rivers is lower, from the influence of evaporation, radiation, and the elevation at which they rise, than that of the country through which they flow, appears subject to some modification as regards great streams whose course lies chiefly through equinoctial regions. Many, like the Nile, derive the great bulk of their water from the rains that fall periodically near the equator when the sun is nearly vertical, and evaporation reduced to its minimum from the saturated state of the atmosphere. The fallen waters derive additional heat in overspreading the wide extent of sand and alluvium that form and skirt the channels through which they roll on towards the ocean; and which, during great part of the year, have been left dry and freely exposed to the rays of a scorching sun. The beds of the most considerable rivers of South India present in many parts of their course, during the dry season, dreary wastes of arid sands, through which the river, reduced to a slender thread, barely finds its way to the sea. The mean of more than 200 observations, taken day and night, on the temperature of the Nile, in July, between Cairo and Thebes, I found to exceed the mean annual temperature of the air at Cairo (72°·4) by 7°·1. The temperature of the river was increased, at the commencement of the inundation in June, by the freshes from Abyssinia from 79° to 80°·5. The observations were taken at Thebes, immediately preceding, and immediately after, the appearance of the turbid milky hue that announces the periodical arrival of Egypt's great benefactor.

The Ganges, though having its source amid the snows of the Himálaya, and pursuing an opposite course to the Nile, that is, a course from northerly latitudes towards the equator, has a mean temperature, as it approaches the ocean, higher than that of the country on its banks. Its mean, between Calcutta and the sea, obtained from a great number of observations by Mr. G. Prinsep, is stated not to be less than 81° Fahr.! while that of Calcutta does not exceed 78°. The Ganges, it is well known, is little indebted to the melting of the snows near its sources, but derives its waters chiefly from the periodical rains that fall near the borders of, and within, the tropics, between 30° and 22° N. lat. During the inundation, its waters in the lower parts of Bengal are spread over a superficies of alluvial soil and sand, more than 100 miles in breadth, the greater part of which has been parched by the droughts prevalent between the monsoons.

In order to obtain a better idea of the degree of heat absorbed and given out by the alluvium of the Nile, the sands and rocks in the beds of the rivers of India, I made the following observations.

In July 1840, a thermometer placed on the dark alluvium, then quite dry, of the Nile opposite the pyramid of Meydún at 12¼ P.M., having its bulb covered 0·1 of an inch with the same alluvium, stood at 136°·5. With, and on, the sand of the desert on the verge of the inundation line, at the same hour, it stood at 121°·5. The temperature of the air at the time, five feet above the surface of the dark alluvium, was 105°·5: the same height above that of the desert, it was 103°·5; sky uncloudled. Although the surface of the sands during the clear serene nights of Egypt is cooled considerably by radiation, still a little below the surface they retain a great portion of the solar heat. In July, at sunrise, the surface of the sandy desert, on the banks of the Nile at Thebes, lat. 25° 26′ N., which during the heat of the day indicated a temperature of 130°, had cooled down to 69°·5, while the thermometer a foot *below* the surface stood at 83°: temperature of the air 75°.

The temperature of the granite rocks in the beds of the Toombuddra and the Kistnah, during the months of May and June, at 2 P.M., I found from 118° to 120°: during the night they cooled down usually to 83°. The temperature of the surface sands in these rivers was slightly higher than that of the granite.

The temperature of rivers whose supply, like those in South India, depends more on the periodical rains than on springs, is consequently influenced by the temperature of the former. That of the monsoon showers, which fell on the western coast near Mangalore during the months of May and June, varied from 78° to 79°, affording a mean of 76°. The rains falling on the elevated table-land of the Ceded districts, from June to December, ranged from 71°·5 to 79°·5, giving the mean 75°·5. The mean general height of the plain, between lat. 13° and 17° N., is 1300 feet above the sea's level. The temperature of the showers was invariably modified by the conditions affecting that of rain water in extra-tropical countries, namely, the elevation at which condensed, and the temperature of the atmospheric strata through which the showers fell.

The temperature of the Brahmapútra river at Sadya in Assam, was found in September by Mr. GRIFFITHS to range from 63° to 70°. That of the air above the river, from 68° to 100°. That of the Indus, by GERARD, in March, near Attock, was 32°.

Temperature of the Ocean on the Equator and between the Tropics.—The influence of the trade-winds, cold currents from high latitudes, frequent showers, evaporation, &c., contribute to cool the air and surface of the ocean at the equator. The extremes of the temperature of the latter, at great distances from land, have been pretty correctly stated by M. ARAGO at 80°·8 and 84°·2. On crossing the line in the Atlantic Ocean (in long. 20°·7 W.) I found the temperature of the sea 84°·5; air in the shade, 87°: in the Indian Ocean (long. 58°·54 E.) 81°·5; air in the shade 82°·5. In the

same oceans, near the land, and in narrow seas, the range between the extremes is much greater than 3°·4. In the Red Sea, from the Straits of Babelmandel to the tropic of Cancer, I found it, in the month of May, to be 6°, viz. from 82° to 88°; and in the Indian Ocean, from lat. 12° to 19°, so much as 8°·5, viz. from 78° to 87°·5. In the Straits of Malacca, in lat. 2° N., it ranged from 80° to 85°·2.

On some parts of the west coast of India (where 123½ inches of rain falls during the year), during the monsoon, the surface of the sea is considerably cooled by the freshes from the numerous rivers and streamlets that descend from the lofty mountains of the Ghants. Off Honáwer, lat. 14° 16′ N., the temperature of the sea during the dry season was 85°·5. During the monsoon it fell to 79°; average temperature of rain water at the time, 75°·7; of rivers, 76°. From its inferior specific gravity, the fresh muddy water from the hills floats on the surface of the sea to considerable distances, without being intimately blended. In the depth of the monsoon, near Mangalore, in 1839, the water was observed to be nearly fresh a mile off the coast; and I have seen the Mediterranean discoloured by the turbid inundation of the Nile to a distance of nearly forty miles from the Damietta embouchure.

Mean Temperature in India.—Colonel Sykes, in his statistics of the Deccan, has already noted one remarkable feature touching the mean temperature of places at elevations on the table-land of India, namely, that it is much higher than the mean for the same places, calculated agreeably to Mayer's formula. To the instances he has cited of this fact, of places on the plateau of the Deccan, may be added the following, occurring on the table-land of South India.

Places.	Feet above sea.	Lat. N.	Observed mean.	Calculated mean.	Difference.
		° ′	°	°	°
Hydrabad ...	1720	17 15	80	74·72	5·28
Nagpore	1101	21 10	80	74·26	5·74
Bellary.....	1600	15 5	80·5	76·12	4·38
Bangalore ..	3000	12 57	74·39	73·05	1·34
Seringapatam	2412	12 25	77·06	74·93	2·13

Among the principal causes of this differential height of temperature,—a difference more remarkable when compared with the indications afforded by the improved formulæ of Brewster, D'Auburisson and Atkinson,—may be enumerated the physical aspect and extent of the elevated plains on which these places stand,—the rapidity with which the drainage water passes off, and consequent little evaporation,—the comparatively flat, or gently undulating surface,—its bareness of vegetation during great part of the year,—the non-influence of alternations of land and sea breezes, by which places near the sea are cooled,—the partial influence of the monsoon and scantiness of rain,—the favourable conditions of the atmosphere for irradiation, and the capacity of the soil for imbibing and giving out the solar heat. The temperature of the granitic soil in the vicinity of Bellary, at 2 P.M., in May, reached 121°; that of the Régur, or black soil, 122°·5: the temperature of the air in the shade, 95°·5: at midnight the temperature of the black soil was still so high as 86°; temperature of the

air 80°. That of a bare rock of granite, the same locality, at 2 P.M., was 120°·5; of black basaltic rock 122°. The temperature of the granite at midnight was 86°·5. Both Bellary and Hydrabad are situated under the shade almost of bare granitic masses, in the midst of plains covered with sheets of the granitic and black régur soils just alluded to, whose almost treeless extent during the hot months is shrunk up and intersected by deep and countless fissures. The climate of the former station is nearly as dry as that of Egypt. In 1838 only 11·25 inches of rain fell during the year. The atmosphere is remarkable for transparency and freedom from clouds. The foregoing views appear to be strengthened by the fact, that the observed mean temperature of the elevated stations of Ootacamund (7221 feet above the sea's level), Mercára (4500 feet), and Candy in Ceylon (1680 feet), are *lower* than their calculated mean temperatures. The calculated mean of Ootacamund is 61°·64, observed mean 55°·8; of Mercára 68°·99, observed mean 65°·58; and of Candy 78°·58, observed mean 73°·3. Now all these places are surrounded by an irregular surface of hill and valley, generally clothed with eternal forest, presenting an extensive radiating and evaporating surface, and shading the drainage of heavy monsoons that lingers in their swampy hollows. The humidity of the atmosphere at these stations is very great; at Mercára, during nearly half the year, its hygrometric condition closely approaches saturation. Hence, favoured by the alternations of land and sea breezes, even close to the sea's level, the low temperatures of some places near the equator, viz. Singapore, lat. 1° 15′ N., mean temperature 80°·7; Malacca, lat. 2° 14′ N., mean temperature 80°·4; Penang, lat. 5° N., mean temperature 80°·5; Province Wellesley, lat. 5° 20′ N., mean temperature 79°·5. The monsoons are distributed over these forest-clad regions of the equator in an almost daily succession of refreshing showers throughout the year. May not the vital functions of the plants, covering large tracts of country, particularly those concerned in their respiration and nutrition, exert an influence in cooling over-heated states of the atmosphere?

It may be further stated, in corroboration of the high temperature of table-lands being mainly produced by the causes referred to above, that the temperature of isolated peaks and summits of ridges, rising with a rapid ascent and confined superficies from their elevated level, appears to diminish in a greater ratio than 1° Fahr. for every 352 feet of ascent; when, perhaps, that of the aggregate height from the sea's level is in strict accordance with this rule. The mean of a month's observations by Lieut. Campbell, at the summit and base of the rock of Raya-Cottah on the table-land of Mysore, above which it is elevated 500 feet, gave a decrease of temperature amounting to 3°·35. The diurnal mean difference between the temperature of the summit of a mountain on the table-land of Bellary, and that of the plain at its base, I found so great as 7°·5 for the 1500 feet of elevation which separates them. This table-land has a mean temperature of nearly 4°·5 above its calculated mean. The difference of temperature of two wells, one at the summit of Mount Sinai, and the other 2000 feet below, amounted to 6°, a result closely approximating that of the comparative observations at Geneva and St. Bernard.

The highest known mean temperature of any place in India is that of Pondicherry, which, though this city stands only a little more than a degree to the south of Madras, is stated to reach 85°·28. That of Madras, in lat. 13° 5′ N., is 80°·42, and of Columbo, more than 5° nearer the equator than Pondicherry, only 80°·75. I am not aware that any reason has been assigned for this extraordinarily high mean temperature; the lower temperature of some wells in the vicinity of Pondicherry leads me to doubt its correctness.

Boussingault's *Mode of ascertaining the Mean Temperature of Tropical Countries.*—An expeditious mode for ascertaining the approximate mean temperature of equinoctial regions has been proposed by M. Boussingault, and recommended to travellers, on occasions where time and opportunity do not admit of the usual means. I hardly need remark, that this method is grounded on the hypothesis, that between the tropics the temperature of the earth's crust is constant at the depth of about a foot (one-third of a metre) beneath its surface, and consists in sinking a thermometer in the soil perforated to this depth, under sheds, huts of natives, or other spots sheltered from direct warmth produced by absorption of the solar heat, from nocturnal radiation, and from the infiltration of rain water. The result of my own experiments in India indicates that the soil at the depth of a foot is subject to an annual, and, in light soils, to a diurnal fluctuation, varying according to the intensity of the sun's rays on the soil surrounding the sheltered spots where the experiments were conducted; and radiation modified by the dry and open, moist and close nature of the soil. During cloudy weather these fluctuations were consequently found at their minimum. The maximum of diurnal fluctuation observed was at Bellary, on the centre of the table-land of peninsular India, in lat. 15° 5′ N., and 1600 feet above the sea's level; mean temperature about 80°·5. The experiments were made in the hot month of May, sky unclouded; the soil was reddish and light in texture, and completely sheltered by a thatched roof. Every precaution enjoined by M. Boussingault was carefully attended to, and fresh holes bored every day.

Experiment.—*First Day.*

	Earth.	Air in Shade.
		°
Sunrise . . .	86°·5	81
2 P.M.	91·3	96·5
Second Day.		
Sunrise . . .	85	78
2 P.M.	89	92
Third Day.		
Sunrise . . .	85·5	78·5
2 P.M.	90	95
Fourth Day.		
Sunrise . . .	87	75
2 P.M.	89	92

At Cassergode, on the west coast, lat. N. 12° 29′, whose mean temperature is about 80°, the diurnal fluctuation amounted to only 1°·5 in cloudy weather. At Mangalore, on the same coast, lat. N. 12° 53′, it amounted on a clear day to 2°·75. The last experiment was made, at my request, by my friend Mr. B. G. Maurice, Madras Medical Service. In stiff clayey soils, at the depth of four feet from the surface, and sheltered to the distance of six yards radius from the spot perforated, the temperature fluctuated but little, and gave a tolerably correct mean of the air. In light sandy soils a greater depth is necessary; and at all times it is advisable to observe the temperature of the perforation in the soil at the coldest and hottest periods of the day, which, with an unclouded sky, will be found to occur at, or just before, sunrise, and from 2 to 3 P.M. Such observations should, if possible, be compared with the temperature of a spring or well of moderate depth, at from six to ten feet below the surface, bearing in mind what has already been stated regarding the causes affecting the temperature of wells and springs.

Temperature of Springs and Wells.

Names of Places.	Position in			Formation in which situate.	Depth to surface of water.	Depth of water.	Temperature of air in shade at time of observation.	Temperature of water.	Approximate annual mean temperature of air.	Months of observation.	Remarks.
	Lat. N.	Long. E.	Approximate height in feet above the sea.		ft.	ft.	° ′	° ′	° ′		
Alexandria	31 13	27 35	Shore.	Limestone.	20	6	79 5	74 5	.....	July.	Large ancient reservoirs underneath the old city, communicating with the surface by narrow shafts, fed by Nile at high water.
Cairo	30 2	28 58	50	Limestone.	21	8	80 0	76 0	72 4	July.	Water brackish; shaft three feet in diameter.
Thebes	25° and 26°	30° and 31°	.....	Limestone.	10	5	82 0	79 0	.....	June.	Water brackish; shaft three feet in diameter.
Mount Sinai (summit)	28 33	34 0	7000	Granite.	16	9	75 0	55 0	.....		Rain-water collected in deep cavity on summit. RUPPELL makes summit 7035 French feet. MORELEY 5956 English feet. Mean of two observations by WELLSTED, 7505; 2500 above Convent. Three last are springs from three to four feet in diameter.
Fount of Elias (ascent of Mount Sinai)	.....	.....	6000	Granite.	14	7	73 4	58 5	.....	June.	
Spring of Mariam (ascent)	.....	.....	5500	Granite.	1	2	79 2	59 5	.....		
Well at foot of Mount Sinai	.....	.....	5000	Granite.	4	20	79 0	61 0	.....	June.	Narrow shaft, about four feet in diameter.
Wells of Tor	28 15	33 38	80	Limestone.	4	1½	84 0	77 2	.....	June.	About four feet in diameter; possibly thermal.
Wells of Ambajeh (Egyptian Desert)	26° and 27°	31° and 32°	200	Limestone.	1	½	84 0	82 5	.....	June.	Spring on surface. Saline, muriate and sulphate of soda.
Wells of Hammamet (Egyptian Desert)	26 10	31 0	700	Sand and sandstone	130	½	85 0	76 2	.....	June.	Brackish. Shaft two or three yards in diameter.
Bombay	.....	.....	Shore.	Trap.	10	5	82 0	79 5	.....	April.	Narrow shaft, four feet in diameter.
Beder	17 49	77 46	2300	Laterite.	200	6	82 0	79 0	77 5	June.	Narrow shaft, four feet in diameter.
Calliany	17 50	77 5	.....	Laterite.	35	10	89 0	78 5	.....	July.	Narrow shaft, four feet in diameter.
Hydrabad	17 15	78 35	1720	Granite.	4	10	87 5	79 5	81 0	June.	Large open spring of pure water, ten or twelve yards in diameter.
Hydrabad	17 15	78 35	1720	Granite.	20	12	87 0	80 0	81 0	June.	Deep wells of pure water, narrow shaft.
Wells between the Kistnah and Hydrabad	15° to 17° 50′	.....	900 to 1720	Granite.	6 to 30	6 to 10	84° to 87°	78° to 80°	79 61	June.	Wells of pure or slightly brackish water.
Gokauk	16 11	74 58	.....	Sandstone.	10	4	78 5	75 5	.....	July.	Shaft four feet in diameter.
Darwar	15 20	75 8	2400	Clay-slate.	12	8	79 5	75 8	75 0	July.	Shaft four feet in diameter.
Ceded districts	.....	.....	500 and 1600	Sandstone. Limestone. Granite.	.....	.....	.....	.....	78 5	July.	This is the average temperature of twenty-one springs and bouries between lat. 13° and 17° N., taken at all seasons of the year.
Udigherry	14 52	79 22	.....	Sandstone.	10	5	82 0	78 5	.....	January.	Shaft five feet.
Bunwassey	14 32	75 8	.....	Laterite.	2	1	72 5	75 8	.....	July.	Open bourie.
Nellore	14 28	80 3	100	Laterite.	5	2	82 0	78 5	.....	January.	Shaft five feet.
Kistnapatam	14 25	80 9	Shore.	Laterite.	10	4	82 2	80 0	.....	January.	Shaft five feet.
Honawer	14 16	79 56	Shore.	Laterite.	4	6	78 0	79 0	78 5	July.	Open well, about four yards square.
Madras	13 5	80 22	Shore.	Granite.	6	12	80 8	80 6	80 42	February.	Shaft five feet in diameter.
Mangalore	12 52	74 52	Shore.	Laterite.	3	20	80 0	80 75 and 81 0	80 21	June.	Shaft six feet in diameter.
Beypoor	11 11	75 53	Shore.	Laterite.	20	6	83 4	81 3	80 5	March.	Shaft four feet in diameter.
Malacca	2 14	102 0	Shore.	Laterite.	40	8	84 0	80 5	80 4	June.	Spring, about three feet square.

Temperature of Rivers.

Names of Places.	Position in			Formation in which situate.	Depth to surface of water.	Depth of water.	Temperature of air in shade at time of observation.	Temperature of water.	Approximate annual mean temperature of air.	Months of observation.	Remarks.
	Lat. N.	Long. E.	Approximate height in feet above the sea.								
	° ′	° ′	ft.			ft.	° ′	° ′	° ′		
Cauvery	12 20	76 47	2412	Gneiss.	.....	12	85 0	77 5	77 06	May.	
Pennaur	14 28	80 3	100	Laterite.	.....	6	82 4	79 5	.....	January.	
Gnornippa river	14 16	75 45	.....	Gneiss.	.....	15	72 5	75 5	.....	July.	
Gnornippa at sea	14 16	75 25	Shore.	Laterite.	.....	10	78 0	78 5	.....	July.	
Rivulets of Western Coast	13° and 14°	75 0	Shore.	Laterite.	.....	.....	77 5	78 0	.....	July.	
Tambuddra	15 44	78 2	880	Limestone.	.....	12	85 0	79 0	.....	May.	Swollen and muddy by monsoon; January coldest month, its temperature was 69° 5′.
Hendri	15 44	78 2	880	Limestone.	.....	10	83 0	78 5	.....	June.	Swollen and muddy by monsoon; January coldest month, its temperature was 69° 5′.
Kistnah	15 57	78 2	910	Limestone.	.....	15	89 0	79 0	.....	June.	Swollen and muddy by monsoon; January coldest month, its temperature was 69° 5′.
Gokauk	16 11	74 56	2800	Sandstone.	.....	12	82 0	75 6	.....	July.	
Birna	17 7	.....	1730	Limestone.	.....	.....	.....	78 0	.....	June.	
Godavery	18 0	.....	130	Granite.	.....	14	79 0	74 5	.....	June.	
Indus, near Attock	.....	.....	.....	.....	.....	.....	.....	32 0	.....	March.	GERARD.
Brahmapútra, in Upper Assam	.....	.....	.....	.....	.....	.....	68° and 100°	63° and 70°	.....	Sept.	GRIFFITHS.
Ganges	21° and 23°	.....	.....	Alluvium.	.....	.....	.....	81 0	78 0	Annual mean.	G. PRINSEP.
Nile	25 and 30	.....	.....	Limestone.	.....	.....	81 0	79 5	.....	June & July.	

Temperature of Thermal Springs.

Names of Places.	Position in			Soil or rock in which situate.	Depth to surface of water.	Depth of water.	Temperature of air in shade at time of observation.	Temperature of water. Fahr.	Approximate mean annual temperature of air.	Months of observation.	Remarks.
	Lat. N.	Long. E.	Approximate height in feet above the sea.		ft.	ft.	°				
Jauri on Sutledge	30° and 32°							130 0			Hamilton. Sulphurous.
Jumnotri	30° 52′		10,849	Granite.				194 0			Hodgson. Ferruginous.
Muktinath	29 9	83° 18′									
Bowitti (Oasis parva, Egypt)	28° and 29°	27° and 28°	300	Sandstone.				92 75			Wilkinson.
El Kasr (Oasis parva, Egypt)	28 and 29	27 and 28	300	Sandstone.				93 5			Wilkinson.
Sonah, near Delhi	28 and 29	76 and 77		Sandstone.				108 0			Ludlow.
Hummám Músa (Wells of Elim?) near Tor	28° 5′	33° 38′	60	Limestone.	2	2½	89	91 6		June.	
El Kasr in Oasis of El Dakhleh	26° and 27°	27° and 28°	250	Limestone.				102 0			Wilkinson.
Sitakhund	25 and 26	86 and 87		Quartz.				140 0			Adam. Tasteless, clear, gaseous; gas not ascertained.
Bheembund	24 and 25	86 and 87						144 0		March.	Buchanan.
Rajaghiri	24 and 25	85 and 86					70	108 0		October.	Fullarton, and As. Journal, vol. iii. Saline.
Hazarybaugh	24 and 25	85 and 86						108 0			
Hazarybaugh	24 and 25	85 and 86						170 0			H. Wilson and Fullarton. Sulph., hyd., mur., and sulph. of soda.
Hazarybaugh	24 and 25	85 and 86						190 0			
Kutkunsandy	23 and 25	86 and 87		Trap and Granite.		1	41	114 0			Fullarton.
Tantotya, near Pachete Hills	23 and 24	86 and 87						190 0			Bell. Slightly chalybeate.
Kyrie	22 and 23	78 and 79		Trap.			86	114 0		February.	Spilsbury. Sulphurous, nearly pure water.
Maljihir	22 and 23	78 and 79		Trap.			92	134 0		February.	Spilsbury. Sulphurous, nearly pure water.
Devaki, Unei	20 and 21	73 and 74		Trap (?).				111° & 130°			Dr. White.
Kais	19° 59′	78° 58′		Trap and Limestone.			81° to 100°	87 0		June.	Malcolmson. Carbonic lime and carbonic acid gas.
Bangha	18 12	81 0	200	Sandstone and Limestone.				110 0			Voysey.
Gondála	18 0	81 17	130	Granite and Trap.			70	120° & 139°			Voysey.
Allayen (Moulmein)	16° and 17°	98 0		Limestone.				137 0		December.	Foley.
Bhuga, near Cuddapul	14 and 15	78° and 79°	560	Sandstone.	2	2½	65° and 90°	88 0	79° 5′	December.	
Spring, near Salem	11° 37′	78° 13′	2000	Gneiss and Hornblende slate.	2	3		84 0		March.	Fischer.
Cannia (Ceylon), seven springs	8° and 9°	81° and 82°		Quartz.			77	86° & 107°			Davy.
Sabung, Malacca	2 and 3	102 and 103	500	Granite.	Surface	3	105° in sun.	130 0	80 5	July.	
Ayer Pannas, Malacca	2° and 3°	102° and 103°	400	Granite.	Surface	2½	89°	113° 5′ and 120°	80 5	March.	

Comparative Register of the Temperature of the Air (in the shade) and of the Sea, from Bombay to Suez. The indications of thermometer are adjusted to those given by the standard of the Royal Society.

Month.	Lat. N.	Long. E.	Noon.		Midnight.		Remarks.
			Air.	Water.	Air.	Water.	
	° ′	° ′	°	°	°	°	
May 1.	18 36	71 41	No obs.		No obs.		Indian and Arabian Seas.
2.	18 5	69 38	87·5	85·5	86·5	84·5	
3.	17 30	67 28	87	86·5	87	No obs.	
4.	16 57	69 12	86	84	86·5	No obs.	
5.	15 29	63 5	87·5	85·5	85	85	
6.	15 52	60 53	87	85·5	85	84·5	
7.	15 19	58 40	85	83	86	84·5	
8.	14 56	56 17	85·5	82·5	85·5	82·5	
9.	14 27	53 56	85·5	84·5	83·5	84	
10.	13 43	51 39	86·5	83·5	84·5	84·5	
11.	13 32	48 43	88	85·2	87	85	
12.	12 46	45 53	89	86·6	87	85·5	Off coast of Arabia.
13.	Aden.	Aden.	89·5	87·8	86·5	86	Back Bay, at anchor.
14.	12 49	43 21	88·7	86	85·5	84·5	Red Sea.
15.	15 14	41 55	88	86	84	84	In sounding, off volcano of Gevel Teer.
16.	17 28	40 20	87·5	87	87	84·5	Sun's rays 115° 2 P.M.
17.	19 55	38 52	90	88	85	85·5	Sun's rays 120°·5 2 P.M.
18.	22 23	37 21	86	84·5	85·5	82	
19.	24 38	36 13	84·2	80·5	82	79	
20.	26 38	34 45	84	80·5	89·5	82	Suez, hot khamsin set in about 10 P.M.

Memoranda supplied by the kindness of a friend from the register kept on board the Honourable East India Company's Steamer Cleopatra, from Bombay to Suez.

Month.	Lat. N.	Long. E.	A.M.		P.M.		Remarks.
			Air.	Water.	Air.	Water.	
			°	°	°	°	
April 2.			89	84	81	78	
3.			84	83	80	78	
4.			84	84	81	83	
5.			81	83	81	83	
6.			80	82	80	82	
7.			No entry.		No entry.		
8.			No entry.		No entry.		
9.			No entry.		No entry.		
10.			No entry.		No entry.		At Aden.
11.			No entry.		No entry.		Passed Straits of Babelmandel.
12.			86	84	86 5	84	
13.			87	84	81	82	
14.			79	82	79	80	
15.			No entry.		No entry.		
16.			84	76	73	71	
17.			75	82	No entry.		Passed Island of Shadwan.
18.			No entry.		No entry.		Suez Bay.

N.B. The latitude and longitude have been omitted in the above register; but after making allowance for the more rapid run of the Cleopatra than that of the vessel in which I left India, and calculating from Bombay to the Straits of Babelmandel, and thence to Suez, an approximation may be made to the vessel's situation at the time of taking the observations. The indications could not be adjusted to the standard thermometer of the Society.

Note on the Thermal Springs of the Peninsula of India.

Since my arrival here my friend Mr. MALCOLMSON has put into my hands the first volume of the Bombay Medical and Physical Transactions, where I find, p. 257, a few notes on the thermal springs in the Konkan, by A. DUNCAN, Esq. The geographical distribution of these springs corroborates the remark in my paper under the head of thermal springs, viz. "that the majority of the springs termed thermal occur in India at or near lines of great faults." The thermal springs mentioned by Mr. DUNCAN lie at the base of the Western Ghaut elevation, intermediate between the mountains and the sea, generally from sixteen to twenty-four miles, or thereabout, inland from the latter. The line of springs follows pretty nearly that of the mountains, viz. nearly north and south, and extends from the vicinity of Surât, or about 21° N. lat. to South Rajapore: they are supposed to exist still further south, following at irregular intervals the line of West Ghauts to Ceylon. Not less than twelve are known to exist between Dasgaun and South Rajapore, viz.—

1 at Oonale in the taluk of Viziadroog.
3 in the Rutnaghirry taluk, at Rajwaree, Tooril and Sungmairy.
1 at Arowlee in the Konedree taluk.
1 at Mat, Hatkumbee Mahal.
1 at Oonale, in the Natoe Palivan Mahal, Severndroog.
3 at Oonale, Jaffrabad Mahal.
1 at Savi, in the Ryghur taluk, Bhar Nergannah.
1 at Oonale, Sankse taluk, Mahal Palee.

12 total.

Oonale is the native term for a hot spring. The temperature of all the springs examined exceeded, with a single exception, 100° FAHR., and amounted to 109°. That of Tooril, which unfortunately was not thermometrically ascertained, appeared to Mr. DUNCAN to be almost at the boiling-point. The water was not found to be mineral, though impregnated with sulphuretted hydrogen. A little higher up, on the hill where the thermal spring No. 1 occurs, is a singular intermittent cold spring, over which a temple has been built. It is resorted to by crowds of Hindus during the season when the fountain periodically flows, viz. during the hot months. A more minute analysis of the water, and a more continued series of thermometric observations, are a great desideratum.

The temperature of a hot spring of Oonye in the jungle between Bansda and Boharee is asserted by the Brahmins to diminish annually at the time of the full moon in April, so as to admit of persons bathing in it at this period, when the natives assemble there in great numbers for that purpose. This assertion was contradicted by the late Dr. WHITE, but the question, I see, has again been raised by the observations of Mr. J. S. LAW, of the Civil Service, who found the temperature of the hottest part of the spring to have diminished at this period from 124° to 94° FAHR. It is probable however that future observations on this supposed singular annual variation will set the matter at rest.

Bombay, July 15, 1842.

III. *An Account of* Newton's *Dial presented to the Royal Society by the Rev.* Charles Turnor, *in a letter addressed to the* Marquis of Northampton, *Pres. R.S., &c. By the Rev.* Charles Turnor, *F.R.S. Communicated by the President.*

Received May 25, 1844,—Read June 13, 1844.

My Lord,

YOUR Lordship having been pleased to express a wish to Captain Smyth that I should furnish a detailed account of the Newtonian Dial which I have had the honour of presenting to the Royal Society, I beg to submit to your Lordship the following particulars. The dial was taken down in the early part of the present year from the south wall of the Manor House at Woolsthorpe*, a hamlet to Colsterworth in the county of Lincoln, the birthplace of Newton.

The house is built of stone, and the dial, now in the possession of the Royal Society, was marked on a large stone in the south wall at the angle of the building, and about six feet from the ground, and which was reduced to its present dimensions for the convenience of carriage. The name of Newton, with the exception of the first two letters, which have been obliterated by the hand of time, will, on close inspection, appear to have been inscribed under the dial in rude and capital letters. There is also another dial marked on the wall, smaller than the former, and not in such good preservation. The above are the only dials about the house which I have been able to discover, nor can I find by inquiry on the spot that more ever existed, though some of Newton's biographers assert that there were several. An opinion has always prevailed that the dials now in being were executed by Newton's own hand when a boy, which appears probable from the well-known fact, that at a very early period of his life he discovered a genius for mechanical contrivances, evinced more particularly by the construction of a windmill of his own invention, and a clock to go by water applied to its machinery. Finding, however, this latter contrivance (however ingenious) to fail in keeping accurate time, it is not improbable, that with a view to secure that object, he formed with his own hands the two dials in question; and very probably the dial now remaining in the wall of the house, from its inferiority in point of construction to that now in the possession of the Royal Society, was his first attempt in dial-making. The gnomons of these dials have unfortunately disappeared many years, but as they are described in some of the printed

* See Woodcut in the next page.

accounts as *clumsy* performances, it may be concluded that they were not the work of a professed mechanic, but were probably formed and applied by NEWTON himself when he constructed the dials.

I trust your Lordship will allow me to express the high satisfaction I feel in seeing this very interesting relic in the possession of that Society of which NEWTON was so distinguished an ornament, and over which he presided more than twenty years.

I must beg your Lordship's permission to add, that for the gratification which I experience on this occasion, I am greatly indebted to my nephew, CHRISTOPHER TURNOR, Esq., of Stoke, Rochford, to whom the manor-house and landed property of NEWTON now belong, and who not only permitted, but kindly encouraged me to offer this valuable relic to that Society, which be, as well as myself, consider as its fittest and most appropriate depository.

I have the honour to be, my Lord,

Your Lordship's obedient humble Servant,

CHARLES TURNOR.

Spa Buildings, Cheltenham,
May 24, 1844.

MANOR-HOUSE, WOOLSTHORPE;

THE BIRTH-PLACE OF

SIR ISAAC NEWTON, P.R.S.,

SHOWING THE SOLAR DIALS WHICH HE MADE WHEN A BOY.

IV. Ἀμόρφωτα, No. I.—*On a Case of Superficial Colour presented by a homogeneous liquid internally colourless.* By Sir John Frederick William Herschel, *Bart., K.H., F.R.S., &c. &c.*

Received January 28, 1845,—Read February 13, 1845.

A CERTAIN variety of fluor spar, of a green colour, from Alston Moor, is well known to mineralogists by its curious property of exhibiting a superficial colour, differing much from its transmitted tint, being a fine blue of a peculiar and delicate aspect like the bloom on a plum, and like that bloom might perhaps be referred to a peculiar texture of the surface, the result of crystallization, were it not that it appears equally on a surface artificially cut and polished. Glasses also are manufactured which, by the agency of a delicate superficial film, consisting apparently of a dull green-coloured powder, and reflecting (or rather dispersing) a green light, exhibit a brownish red tint by transmission; chloride of sulphur, and the infusion of lignum nephriticum are particularized in some books as exhibiting different colours by transmitted and reflected light. As respects the chloride of sulphur, the statement is incorrect, and has originated in a misapprehension of its scale of absorbent action, which (as is the case with many dichromatic media) causes its hue to change from green to red by mere increase of thickness. In the infusion of lignum nephriticum, and in one other instance which has occurred to my notice, the reflected tint arises from suspended particles too minute, or too nearly of the specific gravity of the liquid, to be separated by *subsidence**, the transmitted colour being that of the transparent liquid in which they float, and the particles themselves being opake.

The case which I am about to describe is not precisely parallel to any of these, though far more striking than either. That of the fluor spar presents the closest analogy to it, though from what we know of the impracticability of obliterating the internal structure of mother-of-pearl by any artificial polish, the difference between the solid and fluid states of aggregation precludes any argument from that phenomenon to the one in question.

The sulphate of quinine is well known to be of extremely sparing solubility in water. It is however easily and copiously soluble in tartaric acid. Equal weights of the sulphate and of crystallised tartaric acid†, rubbed up together with addition of a very little water, dissolve entirely and immediately. It is this solution, largely diluted, which exhibits the optical phenomenon in question. Though perfectly trans-

* I write from recollection of an experiment made nearly twenty years ago, and which I cannot repeat for want of a specimen of the wood. I think the *filtered* liquid did *not* exhibit the double colour.

† Citric acid answers equally well.

parent and colourless when held between the eye and the light, or a white object, it yet exhibits in certain aspects, and under certain incidences of the light, an extremely vivid and beautiful celestial blue colour, which, from the circumstances of its occurrence, would seem to originate in those strata which the light first penetrates in entering the liquid, and which, if not strictly superficial, at least exert their peculiar power of analysing the incident rays and dispersing those which compose the tint in question, only through a very small depth within the medium.

To see the colour in question to advantage, all that is requisite is to dissolve the two ingredients above mentioned in equal proportions, in about a hundred times their joint weight of water, and having filtered the solution, pour it into a tall narrow cylindrical glass vessel or test tube, which is to be set upright on a dark-coloured substance before an open window exposed to strong daylight or sunshine, but with no cross lights, or any strong reflected light from behind. If we look down perpendicularly into the vessel so that the visual ray shall graze the internal surface of the glass through a great part of its depth, the whole of that surface of the liquid on which the light first strikes will appear of a lively blue, which as the situation of the eye changes is either fore-shortened into a vivid concave gleam, or opens out into a paler and broader band, as the visual line is more or less oblique to the glass surface.

If the liquid be poured out into another vessel, the descending stream gleams internally from all its undulating inequalities with the same lively yet delicate blue colour, thus clearly demonstrating that contact with a denser medium has no share in producing this singular phenomenon.

The thinnest film of the liquid seems quite as effective in producing this superficial colour as a considerable thickness. For instance, if in pouring it from one glass into another, it be made to trickle down the internal surface of the receiving glass towards the light, or if instead of falling in drops from a filter, the end of the funnel be made to touch the internal surface of the vessel well moistened, so as to spread the descending stream over an extensive surface, the intensity of the colour is such that it is almost impossible to avoid supposing that we have a highly coloured liquid under our view.

By candlelight the gleam is less vivid, and verges more to violet. Analysed by a prism the red rays are found to be almost entirely absent. No signs of polarization were perceived in it, on viewing it through a tourmaline plate turned round in its own plane.

As this phenomenon in all its circumstances is (so far as I am aware) unique in physical optics, I have thought no apology necessary for simply describing, without attempting to pursue it further, which present circumstances do not permit. It would be interesting to know whether the property in question is characteristic of quinine, or is participated in by cinchonine, salicine, or any of the other vegetable alkaloids, which I have not been able to decide for want of specimens.

J. F. W. Herschel.

Collingwood, Jan. 25, 1845.

Received February 20, 1845.

P.S.—Having been obligingly favoured by Professor DANIELL with specimens of very pure cinchonine and salicine, I am enabled to state that they do not possess in the smallest appreciable degree the curious property above shown to belong to quinine.

As regards the latter alkaloid, all the acids I have tried appear to produce the same effect, though not all in an equal degree. The muriatic seems least efficacious; the sulphuric and acetic decidedly the most so. The intensity of the superficial colour produced when either of the latter acids (very dilute) is used, is really surprising.

Only *acid* solutions succeed. After precipitating by excess of potash a solution of quinine, the liquid filtered was very bitter, and of course contained quinine. It however exhibited no trace of superficial colour; but on dropping powdered tartaric acid into the test glass the blue colour was instantly developed, and seen to follow the course of the descending acid.

J. F. W. H.

Feb. 16, 1845.

V. Ἀμόρφωτα, No. II.—*On the Epipölic Dispersion of Light, being a Supplement to a paper entitled, "On a Case of Superficial Colour presented by a homogeneous liquid internally colourless."* By Sir J. F. W. Herschel, *Bart., K.H., F.R.S., &c.*

Received March 6,—Read April 3, 1845.

In reasoning on the peculiar coloured dispersion operated on a portion of a beam of white light intromitted into a solution of sulphate of quinine, it occurred to me as a subject well worthy of inquiry whether the rays so selected for dispersion and thus singularly separated from the rest, were distinguished by any other peculiarity; whether in effect an *analysis* of the incident light into two distinct species *qualitatively* different had been performed, or merely a simple *subdivision*, such as takes place, for instance, in partial reflexion, as in the phenomena of the colours of thin plates. Another interesting subject of inquiry presents itself in the laws which regulate this singular mode of dispersion itself, which, for brevity, I shall venture to call (at least provisionally) *epipölic*, from ἐπιπολὴ, *a surface*, the seat of the dispersion being at or very near the intromitting surface.

As regards the question of analysis, two modes of examination present themselves, viz. either,—1, by subjecting the dispersed portion of the light to experiment, or, 2, the residual portion, which, having escaped dispersion, preserves the unity of its direction; and on that account, as well as by reason of its vastly superior intensity, offers itself more readily to experimental inquiry.

The colour of the dispersed portion being blue, that of the residual beam ought, of course, to verge towards orange. But owing to the large excess of undecomposed white light present, this tendency is inappreciable; and the regularly transmitted beam is not to be distinguished by the eye from white light. Another reason is, that some portion of the dispersed necessarily mingles with the regularly transmitted beam, the medium being equally *permeable* to both; so that in viewing an extensive white surface (the cloudy sky for instance, or a piece of white paper), the regularly transmitted ray reaching the eye in any given direction, that is, from any one point in the luminous surface, has, intermingled with it, a dispersed ray from every other point of that surface, the totality of which goes to restore to it some material portion of the blue light which it lost by dispersion at its intromission.

In the ordinary production of colour in liquids by absorption of the complementary tint, the smallest preference of one over the other coloured rays may be magnified and brought into evidence as a cause of coloration by increasing the thickness of the transmitting medium, or by passing the light successively through

many vessels filled with it. Accordingly it might be supposed that by passing the same incident beam successively through many such dispersive surfaces, the whole of the blue rays would at length be separated from it, and an orange, or red residual beam be left. But this is not the case, the reason of which is to be found in a very remarkable peculiarity in the transmitted light, which may be thus announced.

An epipolized beam of light (meaning thereby a beam which has been once transmitted through a quiniferous solution and undergone its dispersing action) *is incapable of further undergoing epipolic dispersion.*

In proof of this, the following experiments may be adduced.

Exp. 1. A glass jar being filled with a quiniferous solution*, a piece of plate-glass was immersed in it vertically, so as to be entirely covered and to present one face directly to the incident light. In this situation, when viewed by an eye almost perpendicularly over it, so as to graze either surface very obliquely, neither the anterior nor posterior face showed the slightest trace of epipolic colour. Now the light, at its egress from the immersed glass, entered the liquid under precisely the same circumstances as that which, when traversing the anterior surface of the glass jar, underwent epipolic dispersion on first entering the liquid. It had therefore lost a property which it originally possessed, and could not therefore be considered, *qualitatively*, the same light.

Exp. 2. The epipolic tint is developed only on the surface of incidence. When the solution is exposed to light in a glass vessel, the posterior surface, whether viewed internally or externally, is quite colourless. Here again, since ingress and egress into and out of a medium are, optically speaking, convertible, *a qualitative analysis* at the surface of incidence would appear to be indicated.

Exp. 3. A test cylinder filled to the height of two or three inches with the solution was set upright on black velvet, its bottom being also shaded to the depth of half an inch (to prevent reflected light from the bottom from reaching the eye). The epipolic tint being now fully developed, a hollow parallelopiped of plate glass, filled with the same solution, was interposed between the test cylinder and the incident light, side light being at the same time obstructed by screens duly placed. Immediately the epipolic colour in the interior of the cylinder vanished altogether. The transmitting vessel was now emptied of its contents and filled with pure water,

* The solution here used and subsequently referred to (except when otherwise expressed) is formed by adding to sulphuric acid, diluted to such an extent as just to bear being swallowed without pain, about one two-hundredth part of its weight, (the weight, i. e. of the *diluted* acid) of sulphate of quinine. When of this strength it is difficult to believe that a bottle half-filled with it contains a colourless liquid. When shaken, it tinges the glass vividly blue: lively blue gleams are reflected from the interior, and from the capillary ring at the surface level, &c. I may mention that in one instance a rose-coloured solution was formed, which I have never been able to reproduce. The ingredients were taken from the very same parcels which gave the usual colourless solution, and the mixture made in the identical vessel which had just recently served for the same experiments, and which had not even been washed, and from which a colourless solution had just been emptied. If owing to any foreign ingredient accidentally present, the quantity must have been inconceivably minute.

from which its former contents were in no way distinguishable by an eye situated behind it. Being then replaced as before, so as to intercept the light incident on the test cylinder, the epipolic colour was produced, exactly as if nothing had been interposed; a trifling difference of intensity only excepted, which arose from the glass used not being wholly devoid of colour.

Exp. 4. This experiment was varied so as to present a result disengaged from this slight source of uncertainty, and perfectly decisive. A cylindrical jar was coated externally with black paper round three-fourths of its circumference, as was also its bottom, and a ring of the same paper was carried round the cylinder at the bottom so as to cut off light from being internally reflected on its base. In it was set upright a test cylinder of the solution, and the jar was then filled with pure water rising considerably above the solution in the cylinder. When exposed to light as usual, the epipolic tint was finely seen. But on emptying out the water, and introducing in its stead an equal quantity of the quiniferous solution, the tint in question was completely destroyed, whether the surface of the cylinder was viewed from within or from without, proving evidently that no rays susceptible of epipolic dispersion had reached its surface. This result was rendered the more remarkable by an effect of contrast. The *external, upper* portion of the cylinder, above its liquid contents, but below the level of the liquid in the jar, reflected to the eye (or rather the air within it reflected) a pretty strong blue gleam, being no other than the epipolically dispersed light of the anterior surface of the liquid in the jar; while all below (being glass in contact with the liquid on both sides and so deprived of reflective power on both surfaces) was completely dark and almost invisible.

When the interior test cylinder was sloped backwards from the incident light at an angle of about 70° to the horizon, a beautiful and instructive feature was developed. In this situation of things, the interior liquid being as usual the quinine solution, and the exterior pure water; to an eye perpendicularly over the surface, the whole anterior portion of the cylinder from below upwards to the surface of the interior liquid, appeared coated as it were internally with a most delicate and beautiful blue film of extreme tenuity and perfect transparency, presenting a singular ghost-like appearance, easier produced than described. This being seen *through* the cylinder, by an eye situated externally to its prolongation, affords a proof that the epipolic dispersion takes place in all directions: but except in this mode of viewing it the rays dispersed outwards cannot reach the eye, or not in abundance (for which a very oblique incidence is required), being at such an incidence internally and totally reflected by the outer surface of the glass. To see this to advantage an eye-tube internally blackened should be used to guard the eye from extraneous light. Such a tube indeed is generally advantageous in all these experiments.

If, instead of water, the test cylinder be plunged into a solution of quinine, all else remaining as before, the blue film in question *totally disappears*. I tried a great many other liquids, all in fact which I had at hand in sufficient quantity and colour-

less, or but little coloured, in hopes of discovering something which might elucidate the subject. Strong alcohol, solution of corrosive sublimate, ammonia, &c. acted as water; allowing the blue film to be seen externally at a perpendicular incidence of the visual ray to the surface of the liquid. With strong sulphuric acid, and with muriate of lime so concentrated as to be syrupy, this was not possible, but the film became visible, and of its full intensity, on moving the eye forward (i. e. towards the incident light). When sulphate of manganese was used, its delicate pale rose-colour no way prevented a fine exhibition of the blue film (a point to which I shall have occasion to revert). On the other hand, the lemon yellow-colour of nitrate of uranium (a much fuller tint) materially enfeebled, though it did not prevent the formation of the film. This last effect did however appear to be produced by two liquids, viz. pyroxylic spirit in a small degree, and oil of turpentine in a much greater; the effect in this case being very obviously much more than could justly be attributed to a trifling tinge of yellow in the oil (which was not fresh), as I satisfied myself by a comparative experiment with water purposely coloured to a similar tint of greater intensity. Neither of these liquids however was found on trial in the test cylinder, or otherwise, to possess in the smallest degree the property of epipolic dispersion; nor have I found any other liquid which does so.

Exp. 5. Among solids the only one I am acquainted with possessed of a similar property, is the green fluor of Alston Moor, which exhibits by superficial dispersion a fine deep blue colour, very different from the inherent or absorptive colour of the mineral. This is strictly an epipolic tint, as the following experiment will show, and at the same time affords another, and not a little striking confirmation of the general proposition announced in p. 148. I should premise that to see the epipolic colour of the fluor in perfection, it must be laid on black velvet, or the reflexion of light from its posterior surfaces must be destroyed by roughening and coating them with black sealing-wax. In this state, if exposed to daylight at a window, and viewed through a blackened eye-tube, it is seen not as a green, but as a fine deep blue crystal.

If a piece of fluor so prepared be placed in water in a glass standing on black velvet, the blue epipolic colour is seen greatly heightened. But if the water be exchanged for a solution of quinine, this colour is completely destroyed and the surface appears simply black. To make the experiment successfully, the greatest care must be taken to cut off all lateral or reflected light. The arrangement I adopted was, to coat a fluor as above described, and fastening it with black sealing-wax to a wire, to lower it into the coated jar described in Exp. 4, filled alternately with a solution of quinine and with pure water. Using the eye-tube for further precaution, the destruction of the epipolic tint by the solution was quite as complete as if instead of the fluor a test glass full of the quiniferous solution had been used.

It would certainly appear from these experiments that the residual beam after undergoing epipolic dispersion had lost some constituent portion, or otherwise under-

gone some qualitative modification which might be considered as rendering it specifically different from the incident beam. It cannot be the mere tinge of colour which the loss of so small a portion of blue light has given to it. There is still plenty of blue light left, and the experiment on sulphate of manganese proves that a mere *absorption* of a much larger proportion of the blue rays has not the same effect. Moreover the portion of light *dispersed* traverses the solution of quinine with perfect facility, proving that no peculiar absorptive power *is* exercised by that medium on these rays; nor indeed would the separation of such rays by dispersion at the surface in any way tinge *the medium itself* with a complementary tint, but only the residual beam.

I come now to the examination of the dispersed portion of the light. As just remarked, when once *dispersed* it is *freely transmitted*. The epipolic colour is seen as well, in a long test-cylinder filled with the solution, at the bottom of the tube as at the top, when viewed by an eye situated in its axis, supposed vertical. If all light be cut off from the tube by a sheet of black paper rolled round it, except from the lowest inch of its length, that inch is seen to gleam with quite as intense a colour as when the uppermost inch only is so exposed.

I have already had occasion to remark that the epipolic tint is a compound one. To obtain a pure ray for prismatic analysis, a cylindrical glass jar with perpendicular sides was partly filled with the quiniferous liquid and placed in a strong light, the whole anterior side being coated with black paper rising somewhat above the level of the liquid. The eye was then placed in such a position, below that level, that the visual ray proceeding *from* it would suffer total reflexion at the under surface. For comparison, a similar vessel of water, similarly shaded, was placed beside it. The surface of this, so viewed from below, was of course perfectly black, no ray from above being able so to penetrate it as to reach the eye. Not so the quiniferous solution. In this the under surface was wholly visible, of a fine blue colour, considerably deeper in tint than in the ordinary mode of viewing it, though not of so rich and saturated a character as the epipolic blue of the fluor. It was, however, much more luminous, and being thus completely purified from all possible admixture of regularly refracted or reflected light, was well-adapted for prismatic analysis.

By raising the eye exactly to the horizontal level of the surface of the liquid, the whole of that surface became of course foreshortened into a narrow blue line. And in this situation it became perfectly evident that this line was not a mere elongated ellipse, the perspective representation of the circular area of the surface, but a very narrow parallelogram, having a breadth of about a fiftieth of an inch, of a vivid and nearly uniform blue colour over its whole breadth. This proves that the epipolic dispersion takes place *within* the liquid, and almost wholly within a distance not exceeding one-fiftieth of an inch from the surface. I say *almost* wholly; for when a sunbeam was directed downwards on the surface, by total reflexion from the base of a prism, a feeble blue gleam was observed to extend downwards below this vivid

line to nearly half an inch from the surface, thus leaving it doubtful whether some small amount of dispersion may not be effected in the interior of the medium at appreciable depths.

The narrow blue line above described was viewed through a Fraunhofer flint prism. The spectrum was deficient at the red end by the totality of the purer and less refrangible red, nearly the whole orange, and all the yellow. A rich and broad band of fine green light slightly fringed with red on the less refrangible side, passed suddenly, on the more refrangible, to a copious indigo and violet without any intermediately graduating blue. Either from want of sufficient brightness, or from some other cause, no black lines were seen; as far as mere illumination went, the spectrum developed appeared continuous.

It appears from this that no one prismatic ray in particular is selected for epipolic dispersion, but that a certain small per-centage of rays extending over a great range of refrangibility are subject to be so affected, the less refrangible extreme being however wholly excluded, as well as the majority of all below a mean refrangibility.

The epipolic colour is more intense the more oblique the visual ray is to the dispersing surface. This, which would be inexplicable on the supposition of the dispersion being effected rigorously at the *geometrical* surface of the medium, is a necessary consequence of its taking place within a superficial stratum of very small, but appreciable thickness, or according to a law of intensity decreasing with great rapidity as the depth within the medium increases. It has been already shown that the dispersion is not confined to the interior of the liquid, but that a large portion of the dispersed light is directed *outwards*, Exp. 4. The more oblique portions of this (which are also the more intense) require, as is there shown, peculiar management to render them visible. Those whose inclination to the dispersive surface is greater, may also be subjected to ocular inspection, by carefully destroying all regularly reflected or accidental light. Thus, if on a surface of black paper two blots be made, the one of water, the other of a solution of quinine, and if these be laid before a window and viewed through a blackened tube in any direction but that of regular reflexion, the water will appear perfectly black, the quinine feebly blue. But however oblique to the surface the visual ray may be in this case, no great accession of intensity takes place in the epipolic tint, for this obvious reason, *that* the dispersing stratum being *within* the medium, no ray dispersed by it can penetrate the surface, which has not an inclination thereto exceeding 41° 22′, at which angle, therefore, it must cut the stratum, and cannot therefore traverse any great extent of it bodily.

Hence, moreover, on the other hand, the internally dispersed light, at great obliquities to the surface (supposed in contact with air), will be reinforced by all that portion which would have penetrated the surface and gone into the air but for the law of total reflexion; all the dispersed rays, that is to say, whose inclination to the surface is less than 41° 22′. This consideration helps to explain the great comparative intensity which the dispersed beam possesses under such circumstances.

As it has been clearly shown that a beam of white light from which certain rays have been separated by epipolic dispersion is no longer susceptible of producing the epipolic phenomena, it would seem a natural and almost a necessary conclusion, that the rays so separated ought to be *wholly*, or in a very high degree, so dispersed when incident on an epipolizing surface. But the whole history of physical optics is one continued warning against such seeming logical conclusions; and in this case also the conclusion is not borne out by fact. Thus in Exp. 2 and 4, abundance of rays internally dispersed must of necessity have been incident on the new surface presented to them, yet no fresh dispersion whatever took place. I may add too that in experiments made with considerable care to exclude all other light from incidence on a quiniferous surface, but such as had originated in epipolic dispersion, I have not succeeded in obtaining any indication of their susceptibility of being a second time so dispersed. Though from the obscurity of such rays as compared with direct light, these trials can hardly be considered as proving a negative, yet they certainly go very far towards proving the absence of any *peculiar* susceptibility in those rays to this particular affection.

J. F. W. Herschel.

Collingwood, March 1, 1845.

Note added during the Printing.—Professor Graham has had the kindness to transmit to me a specimen of an alkaloid, extracted from the brown coat of the seed of the chestnut, to which the name *Esculine* has been given, which possesses in perfection the property of epipolic dispersion when in dilute solution, in which state it precisely resembles quinine. The same eminent chemist refers also to a peculiar oil called Colophene, formed by the regulated action of sulphuric acid on oil of turpentine, which by his description of its phenomena, must also be an epipolizing liquid of a similar character.

J. F. W. H.

May 12, 1845.

VI. *On the Liquefaction and Solidification of Bodies generally existing as Gases.* By MICHAEL FARADAY, *Esq., D.C.L. F.R.S., Fullerian Prof. Chem. Royal Institution, Foreign Associate of the Acad. Sciences, Paris, Corr. Memb. Royal and Imp. Acadd. of Sciences, Petersburgh, Florence, Copenhagen, Berlin, Göttingen, Modena, Stockholm, &c. &c.*

Received December 19, 1844,—Read January 9, 1845.

THE experiments formerly made on the liquefaction of gases*, and the results which from time to time have been added to this branch of knowledge, especially by M. THILORIER†, have left a constant desire on my mind to renew the investigation. This, with considerations arising out of the apparent simplicity and unity of the molecular constitution of all bodies when in the gaseous or vaporous state, which may be expected, according to the indications given by the experiments of M. CAGNIARD DE LA TOUR, to pass by some simple law into their liquid state, and also the hope of seeing nitrogen, oxygen, and hydrogen, either as liquid or solid bodies, and the latter probably as a metal, have lately induced me to make many experiments on the subject; and though my success has not been equal to my desire, still I hope some of the results obtained, and the means of obtaining them, may have an interest for the Royal Society; more especially as the application of the latter may be carried much further than I as yet have had opportunity of applying them. My object, like that of some others, was to subject the gases to considerable pressure with considerable depression of temperature. To obtain the pressure, I used mechanical force, applied by two air-pumps fixed to a table. The first pump had a piston of an inch in diameter, and the second a piston of only half an inch in diameter; and these were so associated by a connecting pipe, that the first pump forced the gas into and through the valves of the second, and then the second could be employed to throw forward this gas, already condensed to ten, fifteen, or twenty atmospheres, into its final recipient at a much higher pressure.

The gases to be experimented with were either prepared and retained in gas holders or gas jars, or else, when the pumps were dispensed with, were evolved in strong glass vessels, and sent under pressure into the condensing tubes. When the gases were over water, or likely to contain water, they passed, in their way from the air-holder to the pump, through a coil of thin glass tube retained in a vessel filled with a good mixture of ice and salt, and therefore at the temperature of 0° FAHR.; the water that was condensed here was all deposited in the first two inches of the coil.

* Philosophical Transactions, 1823, pp. 160, 189. † Annales de Chimie, 1835, lx. 427, 432.

The condensing tubes were of green bottle glass, being from $\frac{1}{6}$th to $\frac{1}{4}$th of an inch external diameter, and from $\frac{1}{45}$d to $\frac{1}{30}$th of an inch in thickness. They were chiefly of two kinds, about eleven and nine inches in length; the one, when horizontal, having a curve downward near one end to dip into a cold bath, and the other, being in form like an inverted siphon, could have the bend cooled also in the same manner when necessary. Into the straight part of the horizontal tube, and the longest leg of the siphon tube, pressure gauges were introduced when required.

Fig. 1.

Fig. 2.

Caps, stop-cocks and connecting pieces were employed to attach the glass tubes to the pumps, and these, being of brass, were of the usual character of those employed for operations with gas, except that they were small and carefully made. The caps were of such size that the ends of the glass tubes entered freely into them, and had rings or a female screw worm cut in the interior, against which the cement was to adhere. The ends of the glass tubes were roughened by a file, and when a cap was to be fastened on, both it and the end of the tube were made so warm that the cement*, when applied, was thoroughly melted in contact with these parts, before the tube and cap were brought together and finally adjusted to each other. These junctions bore a pressure of thirty, forty, and fifty atmospheres, with only one failure, in above one hundred instances; and that produced no complete separation of parts, but simply a small leak.

The caps, stop-cocks, and connectors, screwed one into the other, having one common screw thread, so as to be combined in any necessary manner. There were also screw plugs, some solid, with a male screw to close the openings or ends of caps, &c., others with a female screw to cover and close the ends of stop-cocks. All these screw joints were made tight by leaden washers; and by having these of different thickness, equal to from $\frac{4}{5}$th to $\frac{1}{8}$th of the distance between one turn of the screw thread and the next, it was easy at once to select the washer which should allow a sufficient compression in screwing up to make all air-tight, and also bring every part of the apparatus into its right position.

* Five parts of resin, one part of yellow bees'-wax, and one part of red ochre, by weight, melted together.

I have often put a pressure of fifty atmospheres into these tubes, and have had no accident or failure (except the one mentioned). With the assistance of Mr. Addams I have tried their strength by a hydrostatic press, and obtained the following results:—A tube having an external diameter of 0·24 of an inch and a thickness of 0·0175 of an inch, burst with a pressure of sixty-seven atmospheres, reckoning one atmosphere as 15 lb. on the square inch. A tube which had been used, of the shape of fig. 1, its external diameter being 0·225 of an inch, and its thickness about 0·03 of an inch, sustained a pressure of 118 atmospheres without breaking, or any failure of the caps or cement, and was then removed for further use.

A tube such as I have employed for generating gases under pressure, having an external diameter of 0·6 of an inch, and a thickness of 0·035 of an inch, burst at twenty-five atmospheres.

Having these data, it was easy to select tubes abundantly sufficient in strength to sustain any force which was likely to be exerted within them in any given experiment.

The gauge used to estimate the degree of pressure to which the gas within the condensing tube was subjected was of the same kind as those formerly described*, being a small tube of glass closed at one end with a cylinder of mercury moving in it. So the expression of ten or twenty atmospheres, means a force which is able to compress a given portion of air into $\frac{1}{10}$th or $\frac{1}{20}$th of its bulk at the pressure of one atmosphere of thirty inches of mercury. These gauges had their graduation marked on them with a black varnish, and also with Indian ink:—there are several of the gases which, when condensed, cause the varnish to liquefy, but then the Indian ink stood. For further precaution, an exact copy of the gauge was taken on paper, to be applied on the outside of the condensing tube. In most cases, when the experiment was over, the pressure was removed from the interior of the apparatus, to ascertain whether the mercury in the gauge would return back to its first or starting-place.

For the application of cold to these tubes a bath of Thilorier's mixture of solid carbonic acid and ether was used. An earthenware dish of the capacity of four cubic inches or more was fitted into a similar dish somewhat larger, with three or four folds of dry flannel intervening, and then the bath mixture was made in the inner dish. Such a bath will easily continue for twenty or thirty minutes, retaining solid carbonic acid the whole time; and the glass tubes used would sustain sudden immersion in it without breaking.

But as my hopes of any success beyond that heretofore obtained depended more upon depression of temperature than on the pressure which I could employ in these tubes, I endeavoured to obtain a still greater degree of cold. There are, in fact, some results producible by cold which no pressure may be able to effect. Thus, solidification has not as yet been conferred on a fluid by any degree of pressure. Again, that beautiful condition which Cagniard de la Tour has made known, and

* Philosophical Transactions, 1823, p. 192.

which comes on with liquids at a certain heat, may have its point of temperature for some of the bodies to be experimented with, as oxygen, hydrogen, nitrogen, &c., below that belonging to the bath of carbonic acid and ether; and, in that case, no pressure which any apparatus could bear would be able to bring them into the liquid or solid state.

To procure this lower degree of cold, the bath of carbonic acid and ether was put into an air-pump, and the air and gaseous carbonic acid rapidly removed. In this way the temperature fell so low, that the vapour of carbonic acid given off by the bath, instead of having a pressure of one atmosphere, had only a pressure of $\frac{1}{25}$th of an atmosphere, or 1·2 inch of mercury; for the air-pump barometer could be kept at 28·2 inches when the ordinary barometer was at 29·4. At this low temperature the carbonic acid mixed with the ether was not more volatile than water at the temperature of 86°, or alcohol at ordinary temperatures.

In order to obtain some idea of this temperature, I had an alcohol thermometer made, of which the graduation was carried below 32° Fahr., by degrees equal in capacity to those between 32° and 212°. When this thermometer was put into the bath of carbonic acid and ether surrounded by the air, but covered over with paper, it gave the temperature of 106° below 0°. When it was introduced into the bath under the air-pump, it sank to the temperature of 166° below 0°; or 60° below the temperature of the same bath at the pressure of one atmosphere, *i. e.* in the air. In this state the ether was very fluid, and the bath could be kept in good order for a quarter of an hour at a time.

As the exhaustion proceeded I observed the temperature of the bath and the corresponding pressure, at certain other points, of which the following may be recorded:— The external barometer was 29·4 inches:

	inch.		Fahr.
when the mercury in the air-pump barometer was	1	the bath temperature was	−106°,
.. ..	10	.. ..	−112½,
.. ..	20	.. ..	−121,
.. ..	22	.. ..	−125,
.. ..	24	.. ..	−131,
.. ..	26	.. ..	−139,
.. ..	27	.. ..	−146,
.. ..	28	.. ..	−160,
.. ..	28·2	.. ..	−166;

but as the thermometer takes some time to acquire the temperature of the bath, and the latter was continually falling in degree; as also the alcohol thickens considerably at the lower temperature, there is no doubt that the degrees expressed are not so low as they ought to be, perhaps even by 5° or 6° in most cases.

With *dry* carbonic acid under the air-pump receiver I could raise the pump barometer to twenty-nine inches when the external barometer was at thirty inches.

The arrangement by which this cooling power was combined in its effect on gases with the pressure of the pumps, was very simple in principle. An air-pump receiver open at the top was employed; the brass plate which closed the aperture had a small brass tube about six inches long, passing through it air-tight by means of a stuffing-box, so as to move easily up and down in a vertical direction. One of the glass condensing siphon tubes, already described, fig. 1, was screwed on to the lower end of the sliding tube, and the upper end of the latter was connected with a communicating tube in two lengths, reaching from it to the condensing pumps; this tube was small, of brass, and 9½ feet in length; it passed six inches horizontally from the condensing pumps, then rose vertically for two feet, afterwards proceeded horizontally for seven feet, and finally turned down and was immediately connected with the sliding tube. By this means the latter could be raised and lowered vertically, without any strain upon the connexions, and the condensing tube lowered into the cold bath *in vacuo*, or raised to have its contents examined at pleasure. The capacity of the connecting tubes beyond the last condensing pump was only two cubic inches.

When experimenting with any particular gas, the apparatus was put together fast and tight, except the solid terminal screw-plug at the short end of the condensing tube, which being the very extremity of the apparatus, was left a little loose. Then, by the condensing pumps, abundance of gas was passed through the apparatus to sweep out every portion of air, after which the terminal plug was screwed up, the cold bath arranged, and the combined effects of cold and pressure brought to unite upon the gas.

There are many gases which condense at less than the pressure of one atmosphere when submitted to the cold of a carbonic acid bath in air (which latter can upon occasions be brought considerably below —106° Fahr.). These it was easy, therefore, to reduce, by sending them through small conducting tubes into tubular receivers placed in the cold bath. When the receivers had previously been softened in a spirit lamp flame, and narrow necks formed on them, it was not difficult by a little further management, hermetically to seal up these substances in their condensed state. In this manner chlorine, cyanogen, ammonia, sulphuretted hydrogen, arseniuretted hydrogen, hydriodic acid, hydrobromic acid, and even carbonic acid, were obtained, sealed up in tubes in the liquid state; and euchlorine was also secured in a tube receiver with a cap and screw-plug. By using a carbonic acid bath, first cooled *in vacuo*, there is no doubt other condensed gases could be secured in the same way.

The fluid carbonic acid was supplied to me by Mr. Addams, in his perfect apparatus, in portions of about 220 cubic inches each. The solid carbonic acid, when produced from it, was preserved in a glass; itself retained in the middle of three concentric glass jars, separated from each other by dry jackets of woollen cloth. So effectual was this arrangement, that I have frequently worked for a whole day of twelve and fourteen hours, having solid carbonic acid in the reservoir, and enough for all

the baths I required during the whole time, produced by one supply of 220 cubic inches*.

By the apparatus, and in the manner, now described, all the gases before condensed were very easily reduced, and some new results were obtained. When a gas was liquefied, it was easy to close the stop-cock, and then remove the condensing tube with the fluid from the rest of the apparatus. But in order to preserve the liquid from escaping as gas, a further precaution was necessary; namely, to cover over the exposed end of the stop-cock by a blank female screw-cap and leaden washer, and also to tighten perfectly the screw of the stop-cock plug. With these precautions I have kept carbonic acid, nitrous oxide, fluosilicon, &c. for several days.

Even with gases which could be condensed by the carbonic acid bath in air, this apparatus in the air-pump had, in one respect, the advantage; for when the condensing tube was lifted out of the bath into the air, it immediately became covered with hoar frost, obscuring the view of that which was within; but *in vacuo* this was not the case, and the contents of the tube could be very well examined by the eye.

Olefiant gas.—This gas condensed into a clear, colourless, transparent fluid, but did not become solid even in the carbonic acid bath *in vacuo*; whether this was because the temperature was not low enough, or for other reasons referred to in the account of euchlorine, is uncertain.

The pressure of the vapour of this substance at the temperature of the carbonic acid bath in air (−103° Fahr.) appeared singularly uncertain, being on different occasions, and with different specimens, 3·7, 8·7, 5 and 6 atmospheres. The Table below shows the tension of vapour for certain degrees below 0° Fahr., with two different specimens obtained at different times, and it will illustrate this point.

Fahr.	Atmospheres.	Atmospheres.
−100°	4·60	9·30
− 90	5·68	10·26
− 80	6·92	11·33
− 70	8·32	12·52
− 60	9·88	13·86
− 50	11·72	15·36
− 40	13·94	17·05
− 30	16·56	18·98
− 20	19·58	21·23
− 10		23·89
0		27·18
10		31·70
20		36·80
30		42·50

* On one occasion the solid carbonic acid was exceedingly electric, but I could not produce the effect again: it was probably connected with the presence of oil which was in the carbonic acid box; neither it nor the fila-

I have not yet resolved this irregularity, but believe there are two or more substances, physically, and perhaps occasionally chemically different, in olefiant gas; and varying in proportion with the circumstances of heat, proportions of ingredients, &c. attending the preparation.

The fluid affected the resin of the gauge graduation, and probably also the resin of the cap cement, though slowly.

Hydriodic acid.—This substance was prepared from the iodide of phosphorus by heating it with a very little water. It is easily condensable by the temperature of a carbonic acid bath: it was redistilled, and thus obtained perfectly pure.

The acid may be obtained either in the solid or liquid, or (of course) in the gaseous state. As a solid it is perfectly clear, transparent, and colourless; having fissures or cracks in it resembling those that run through ice. Its solidifying temperature is nearly $-60°$ Fahr., and then its vapour has not the pressure of one atmosphere; at a point a little higher it becomes a clear liquid, and this point is close upon that which corresponds to a vaporous pressure of one atmosphere. The acid dissolves the cap cement and the bitumen of the gauge graduation; and appears also to dissolve and act on fat, for it leaked by the plug of the stop-cock with remarkable facility. It acts on the brass of the apparatus, and also on the mercury in the gauge. Hence the following results as to pressures and temperatures are not to be considered more than approximations:—

At 0° Fahr. pressure was 2·9 atmospheres.
At 32° Fahr. pressure was 3·97 atmospheres.
At 60° Fahr. pressure was 5·86 atmospheres.

Hydrobromic acid.—This acid was prepared by adding to perbromide of phosphorus* about one-third of its bulk of water in a proper distillatory apparatus formed of glass tube, and then applying heat to distil off the gaseous acid. This being sent into a very cold receiver, was condensed into a liquid, which being rectified by a second distillation, was then experimented with.

Hydrobromic acid condenses into a clear colourless liquid at 100° below 0°, or lower, and has not the pressure of one atmosphere at the temperature of the carbonic acid bath in air. It soon obstructs and renders the motion of the mercury in the air-gauge irregular, so that I did not obtain a measure of its elastic force; but it is less than that of muriatic acid. At and below the temperature of $-124°$ Fahr. it is a

ments of ice which formed on it in the air conducted, for when touched it preserved its electric state. Believing as yet that the account I have given of the cause of the electric state of an issuing jet of steam and water (Phil. Trans. 1843, p. 17) is the true one, I conclude that this also was a case of the production of electricity simply by friction, and unconnected with vaporization.

* The bromides of phosphorus are easily made without risk of explosion. If a glass tube be bent so as to have two depressions, phosphorus placed in one and bromine in the other; then by inclining the tube, the vapour of bromine can be made to flow gradually on to, and combine with, the phosphorus. The fluid protobromide is first formed, and this is afterwards converted into solid perbromide. The excess of bromine may be dissipated by the careful application of heat.

solid, transparent, crystalline body. It does not freeze until reduced much lower than this temperature; but being frozen by the carbonic acid bath *in vacuo*, it remains a solid until the temperature in rising attains to −124°.

Fluosilicon.—I found that this substance in the gaseous state might be brought in contact with the oil and metal of the pumps, without causing injury to them, for a time sufficiently long to apply the joint process of condensation already described. The substance liquefied under a pressure of about nine atmospheres at the lowest temperature, or at 160° below 0°; and was then clear, transparent, colourless, and very fluid like hot ether. It did not solidify at any temperature to which I could submit it. I was able to preserve it in the tube until the next day. Some leakage had then taken place (for it ultimately acted on the lubricating fat of the stop-cock), and there was no liquid in the tube at common temperatures; but when the bend of the tube was cooled to 32° by a little ice, fluid appeared: a bath of ice and salt caused a still more abundant condensation. The pressure appeared then to be above thirty atmospheres, but the motion of the mercury in the gauge had become obstructed through the action of the fluosilicon, and no confidence could be reposed in its indications.

Phosphuretted hydrogen.—This gas was prepared by boiling phosphorus in a strong pure solution of caustic potassa, and the gas was preserved over water in a dark room for several days to cause the deposition of any mere vapour of phosphorus which it might contain. It was then subjected to high pressure in a tube cooled by a carbonic acid bath, which had itself been cooled under the receiver of the air-pump. The gas in its way to the pumps passed through a long spiral of thin narrow glass tube immersed in a mixture of ice and salt at 0°, to remove as much water from it as possible.

By these means the phosphuretted hydrogen was liquefied; for a pure, clear, colourless, transparent and very limpid fluid appeared, which could not be solidified by any temperature applied, and which when the pressure was taken off immediately rose again in the form of gas. Still the whole of the gas was not condensable into this fluid. By working the pumps the pressure would rise up to twenty-five atmospheres at this very low temperature, and yet at the pressure of two or three atmospheres and the same temperature, liquid would remain. There can be no doubt that phosphuretted hydrogen condensed, but neither can there be a doubt that some other gas, not so condensable, was also present, which perhaps may be either another phosphuretted hydrogen or hydrogen itself.

Fluoboron.—This substance was prepared from fluor spar, fused boracic acid and strong sulphuric acid, in a tube generator such as that already described, and conducted into a condensing tube under the generating pressure. The ordinary carbonic acid bath did not condense it, but the application of one cooled under the air-pump caused its liquefaction, and fluoboron then appeared as a very limpid, colourless, clear fluid, showing no signs of solidification, but when at the lowest temperature mobile as hot ether. When the pressure was taken off, or the temperature raised, it returned into the state of gas.

The following are some results of pressure, all that I could obtain with the liquid in my possession; for, as the liquid is light and the gas heavy, the former rapidly disappears in producing the latter. They make no pretensions to accuracy, and are given only for general information.

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
−100	4·61	−72	9·23	−62	11·54.
− 82	7·5	−66	10·00		

The preceding are, as far as I am aware, new results of the liquefaction and solidification of gases. I will now briefly add such other information respecting solidification, pressure, &c., as I have obtained with gaseous bodies previously condensed. As to pressure, considerable irregularity often occurred, which I cannot always refer to its true cause; sometimes a little of the compressed gas would creep by the mercury in the gauge, and increase the volume of inclosed air; and this varied with different substances, probably by some tendency which the glass had to favour the condensation of one (by something analogous to hygrometric action) more than another. But even when the mercury returned to its place in the gauge, there were anomalies which seemed to imply, that a substance, supposed to be one, might be a mixture of two or more. It is, of course, essential that the gauge be preserved at the same temperature throughout the observations.

Muriatic acid.—This substance did not freeze at the lowest temperature to which I could attain. Liquid muriatic acid dissolves bitumen; the solution, liberated from pressure, boils, giving off muriatic acid vapour, and the bitumen is left in a solid frothy state, and probably altered, in some degree, chemically. The acid unites with and softens the resinous cap cement, but leaves it when the pressure is diminished. The following are certain pressures and temperatures which, I believe, are not very far from truth; the marked numbers are from experiment.

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
∪−100	1·80	∪− 53	5·83	∪− 5	13·88
∪− 92	2·28	−50	6·30	∪ 0	15·04
− 90	2·38	∪−42	7·40	10	17·74
∪− 83	2·90	−40	7·68	20	21·09
− 80	3·12	∪−33	8·53	∪ 25	23·08
∪− 77	3·37	−30	9·22	30	25·32
− 70	4·02	∪−22	10·66	∪ 32	26·20
∪− 67	4·26	−20	10·92	40	30·67
− 60	5·08	−10	12·82		

The result formerly obtained* was forty atmospheres at the temperature of 50° Fahr.

* Philosophical Transactions, 1823, p. 198.

Sulphurous acid.—When liquid, it dissolves bitumen. It becomes a crystalline, transparent, colourless, solid body, at −105° Fahr.; when partly frozen the crystals are well-formed. The solid sulphurous acid is heavier than the liquid, and sinks freely in it. The following is a table of pressures in atmospheres of 30 inches mercury, of which the marked results are from many observations, the others are interpolated. They differ considerably from the results obtained by Bunsen*, but agree with my first and only result.

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
0	0·725	40	1·78	76·8	3·50
10	0·92	46·5	2·00	85	4·00
⌣14	1·00	⌣48	2·06	⌣ 90	4·35
⌣19	1·12	⌣56	2·42	93	4·50
⌣23	1·23	58	2·50	98	5·00
⌣26	1·33	⌣64	2·76	⌣100	5·16
31·5	1·50	68	3·00	104	5·50
⌣32	1·53	⌣73·5	3·28	110	6·00
⌣33	1·57				

Sulphuretted hydrogen.—This substance solidifies at 122° Fahr. below 0°, and is then a white crystalline translucent substance, not remaining clear and transparent in the solid state like water, carbonic acid, nitrous oxide, &c., but forming a mass of confused crystals like common salt or nitrate of ammonia, solidified from the melted state. As it fuses at temperatures above −122°, the solid part sinks freely in the fluid, indicating that it is considerably heavier. At this temperature the pressure of its vapour is less than one atmosphere, not more, probably, than 0·8 of an atmosphere, so that the liquid allowed to evaporate in the air would not solidify as carbonic acid does.

The following is a table of the tension of its vapour, the marked numbers being close to experimental results, and the rest interpolated. The curve resulting from these numbers, though coming out nearly identical in different series of experiments, is apparently so different in its character from that of water or carbonic acid, as to leave doubts on my mind respecting it, or else of the identity of every portion of the fluid obtained, yet the crystallization and other characters of the latter seemed to show that it was a pure substance.

* Bibliothèque Universelle, 1839, xxiii. p. 185.

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
−100	1·02	−50	2·35	0	6·10
∪− 94	1·09	∪−45	2·59	10	7·21
∪− 90	1·15	∪−40	2·86	20	8·44
∪− 83	1·27	−30	3·49	∪26	9·36
− 80	1·33	∪−24	3·95	30	9·94
∪− 74	1·50	∪−20	4·24	40	11·84
− 70	1·59	∪−16	4·60	∪48	13·70
∪− 68	1·67	−10	5·11	50	14·14
− 60	1·93	∪− 2	5·90	∪52	14·60
∪− 58	2·00				

Carbonic acid.—The solidification of carbonic acid by M. Thilorier is one of the most beautiful experimental results of modern times. He obtained the substance, as is well known, in the form of a concrete white mass like fine snow, aggregated. When it is melted and resolidified by a bath of low temperature, it then appears as a clear, transparent, crystalline, colourless body, like ice; so clear, indeed, that at times it was doubtful to the eye whether anything was in the tube, yet at the same time the part was filled with solid carbonic acid. It melts at the temperature of −70° or −72° Fahr., and the solid carbonic acid is heavier than the fluid bathing it. The solid or liquid carbonic acid at this temperature has a pressure of 5·33 atmospheres nearly. Hence it is easy to understand the readiness with which liquid carbonic acid, when allowed to escape into the air, exerting only a pressure of one atmosphere, freezes a part of itself by the evaporation of another part.

Thilorier gives −100° C. or −148° Fahr. as the temperature at which carbonic acid becomes solid. This however is rather the temperature to which solid carbonic acid can sink by further evaporation in the air, and is a temperature belonging to a pressure, not only lower than that of 5·33 atmospheres, but even much below that of one atmosphere. This cooling effect to temperatures below the boiling-point often appears. A bath of carbonic acid and ether exposed to the air will cool a tube containing condensed solid carbonic acid, until the pressure within the tube is less than one atmosphere; yet, if the same bath be covered up so as to have the pressure of one atmosphere of carbonic acid vapour over it, then the temperature is such as to produce a pressure of 2·5 atmospheres by the vapour of the solid carbonic acid within the tube.

The estimates of the pressure of carbonic acid vapour are sadly at variance; thus, Thilorier* says it has a pressure of 26 atmospheres at −4° Fahr., whilst Addams† says that for that pressure it requires a temperature of 30°. Addams gives the pressure about 27½ atmospheres at 32°, but Thilorier and myself‡ give it as 36 atmospheres at the same temperature. At 50° Brunel§ estimates the pressure as 60

* Annales de Chimie, 1835, lx. 427, 432.

† Report of British Association, 1838, p. 70.

‡ Philosophical Transactions, 1823, p. 193.

§ Royal Institution Journal, xxi. 132.

atmospheres, whilst Addams makes it only 34·67 atmospheres. At 86° Thilorier finds the pressure to be 73 atmospheres; at 4° more, or 90°, Brunel makes it 120 atmospheres; and at 10° more, or 100°, Addams makes it less than Thilorier at 86°, and only 62·32 atmospheres; even at 150° the pressure with him is not quite 100 atmospheres.

I am inclined to think that at about 90° Cagniard de la Tour's state comes on with carbonic acid. From Thilorier's data we may obtain the specific gravity of the liquid and the vapour over it at the temperature of 86° Fahr., and the former is little more than twice that of the latter; hence a few degrees more of temperature would bring them together, and Brunel's result seems to imply that the state was then on, but in that case Addams's results could only be accounted for by supposing that there was a deficiency of carbonic acid. The following are the pressures which I have recently obtained:—

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
∪—111	1·14	—60	6·97	∪— 4	21·48
—110	1·17	∪—56	7·70	0	22·84
∪—107	1·36	—50	8·88	∪ 5	24·75
—100	1·85	—40	11·07	∪ 10	26·82
∪— 95	2·28	∪—34	12·50	∪ 15	29·09
— 90	2·77	—30	13·54	20	30·65
∪— 83	3·60	∪—23	15·45	∪ 23	33·15
— 80	3·93	—20	16·30	30	37·19
∪— 75	4·60	∪—15	17·80	∪ 32	38·50
— 70	5·33	—10	19·38		

Carbonic acid is remarkable amongst bodies for the high tension of the vapour which it gives off whilst in the solid or glacial state. There is no other substance which at all comes near it in this respect, and it causes an inversion of what in all other cases is the natural order of events. Thus, if, as is the case with water, ether, mercury or any other fluid, that temperature at which carbonic acid gives off vapour equal in elastic force to one atmosphere, be called its boiling-point; or, if (to produce the actual effect of ebullition) the carbonic acid be plunged below the surface of alcohol or ether, then we shall perceive that the freezing and boiling-points are inverted, i. e. that the freezing-point is the hotter, and the boiling-point the colder of the two, the latter being about 50° below the former.

Euchlorine.—This substance was easily converted from the gaseous state into a solid crystalline body, which, by a little increase of temperature, melted into an orange-red fluid, and by diminution of temperature again congealed; the solid euchlorine had the colour and general appearance of bichromate of potassa; it was moderately hard, brittle and translucent; and the crystals were perfectly clear. It melted at the temperature of 75° below 0°, and the solid portion was heavier than the liquid.

When in the solid state it gives off so little vapour that the eye is not sensible of its presence by any degree of colour in the air over it when looking down a tube four inches in length, at the bottom of which is the substance. Hence the pressure of its vapour at that temperature must be very small.

Some hours after, wishing to solidify the same portion of euchlorine which was then in a liquid state, I placed the tube in a bath at −110°, but could not succeed either by continuance of the tube in the bath, or shaking the fluid in the tube, or opening the tube to allow the full pressure of the atmosphere; but when the liquid euchlorine was touched by a platinum wire it instantly became solid, and exhibited all the properties before described. There are many similar instances amongst ordinary substances, but the effect in this case makes me hesitate in concluding that all the gases which as yet have refused to solidify at temperatures as low as 166° below 0°, cannot acquire the solid state at such a temperature.

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Nitrous oxide.—This substance was obtained *solid* by the temperature of the carbonic acid bath *in vacuo*, and appeared as a beautiful clear crystalline colourless body. The temperature required for this effect must have been very nearly the lowest, perhaps about 150° below 0°. The pressure of the vapour rising from the solid nitrous oxide was less than one atmosphere.

Hence it was concluded that liquid nitrous oxide could not freeze itself by evaporation at one atmosphere, as carbonic acid does; and this was found to be true, for when a tube containing much liquid was freely opened, so as to allow evaporation down to one atmosphere, the liquid boiled and cooled itself, but remained a liquid. The cold produced by the evaporation was very great, and this was shown by putting the part of the tube containing the liquid nitrous oxide, into a cold bath of carbonic acid, for the latter was like a hot bath to the former, and instantly made it boil rapidly.

I kept this substance for some weeks in a tube closed by stop-cocks and cemented caps. In that time there was no action on the bitumen of the graduation, nor on the cement of the caps; these bodies remained perfectly unaltered.

Hence it is probable that this substance may be used in certain cases, instead of carbonic acid, to produce degrees of cold far below those which the latter body can supply. Down to a certain temperature, that of its solidification, it would not even require ether to give contact, and below that temperature it could easily be used mingled with ether; its vapour would do no harm to an air-pump, and there is no doubt that the substance placed *in vacuo* would acquire a temperature lower than any as yet known, perhaps as far below the carbonic acid bath *in vacuo* as that is below the same bath in air.

This substance, like olefiant gas, gave very uncertain results at different times as to the pressure of its vapour; results which can only be accounted for by supposing that there are two different bodies present, soluble in each other, but differing in the elasticity of their vapour. Four different portions gave at the same temperature,

namely, −106° Fahr., the following great differences in pressure, 1·66; 4·4; 5·0; and 6·3 atmospheres, and this after the elastic atmosphere left in the tubes at the conclusion of the condensation had been allowed to escape, and be replaced by a portion of the respective liquids which then rose in vapour. The following Table gives certain results with a portion of liquid which exerted a pressure of six atmospheres at −106° Fahr.

Fahr.	Atmospheres.	Atmospheres.
−40°	10·20	
−35	10·95	
−30	11·80	
−25	12·75	
−20	13·80	
−15	14·95	
−10	16·20	
− 5	17·55	
0	19·05	24·40
5	20·70	26·08
10	22·50	27·84
15	24·45	29·68
20	26·55	31·62
25	28·85	33·66
30		35·82
35		38·10

The second column expresses the pressures given as the fluid was raised from low to higher temperatures. The third column shows the pressures given the next day with the same tube after it had attained to and continued at the atmospheric temperature for some hours. There is a difference of four or five atmospheres between the two, showing that in the first instance the previous low temperature had caused the solution of a more volatile part in the less volatile and liquid portion, and that the prolonged application of a higher temperature during the night had gradually raised it again in vapour. This result occurred again and again with the same specimen*.

Cyanogen.—This substance becomes a solid transparent crystalline body, as Bunsen has already stated†, which raised to the temperature of −30° Fahr. then liquefies. The solid and liquid appear to be nearly of the same specific gravity, but the solid is perhaps the denser of the two.

* This substance is one of those which I liquefied in 1823 (see Philosophical Transactions). Since writing the above I perceive that M. Natterer has condensed it into the liquid state by the use of pumps only (see Comptes Rendus, 1844, 18th Nov. p. 1111), and obtained the liquid in considerable quantities. The non-solidification of it by exposure to the air perfectly accords with my own results.

† Bibliothèque Universelle, 1839, xxiii. p. 184.

The mixed solid and liquid substance yields a vapour of rather less pressure than one atmosphere. In accordance with this result, if the liquid be exposed to the air, it does not freeze itself as carbonic acid does.

The liquid tends to distil over and condense on the cap cement and bitumen of the gauge, but only slightly. When cyanogen is made from cyanide of mercury sealed up hermetically in a glass tube, the cyanogen distils back and condenses in the paracyanic residue of the distillation, but the pressure of the vapour at common temperatures is still as great, or very nearly so, as if the cyanogen were in a clean separate liquid state.

A measured portion of liquid cyanogen was allowed to escape and expand into gas. In this way one volume of liquid at the temperature of 63° Fahr. gave 393·9 volumes of gas at the same temperature and the barometric pressure of 30·2 inches. If 100 cubic inches of the gas be admitted to weigh 55·5 grains, then a cubic inch of the liquid would weigh 218·6 grains. This gives its specific gravity as 0·866. When first condensed I estimated it as nearly 0·9.

Cyanogen is a substance which yielded on different occasions results of vaporous tension differing much from each other, though the substance appeared always to be pure. The following are numbers in which I place some confidence, the pressures being in atmospheres of 30 inches of mercury, and the marked results experimental*.

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
0°	1·25	⌣38·5	2·72	77°	5·00
8·5	1·5	⌣44·5	3·00	⌣79	5·16
⌣10	1·53	⌣48	3·17	83	5·50
15	1·72	⌣50	3·28	88·3	6·00
⌣20	1·89	⌣52	3·36	⌣93·5	6·50
22·8	2·00	54·3	3·50	⌣95	6·64
⌣27	2·20	⌣63	4·00	98·4	7·00
⌣32	2·37	⌣70	4·50	⌣103	7·50
34·5	2·50	⌣74	4·79		

Ammonia.—This body may be obtained as a *solid*, white, translucent, crystalline substance, melting at the temperature of 103° below 0°; at which point the solid substance is heavier than the liquid. In that state the pressure of its vapour must be very small.

Liquid ammonia at 60° was allowed to expand into ammoniacal gas at the same temperature; one volume of the liquid gave 1009·8 volumes of the gas, the barometer being at the pressure of 30·2 inches. If 100 cubic inches of ammoniacal gas be allowed to weigh 18·28 grains, it will give 184·6 grains as the weight of a cubic inch of liquid ammonia at 60°. Hence its specific gravity at that temperature will be 0·731. In the old experiments I found by another kind of process that its specific gravity was 0·76 at 50°.

* See Bunsen's results, Bibliothèque Universelle, 1839, xxiii. p. 185.

The following is a table of the pressure of ammonia vapour, the marked results, as before, being those obtained by experiment:—

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
∪0°	2·48	∪41°	5·10	∪61·3	7·00
0·5	2·50	∪44	5·36	∪65·6	7·50
∪9·3	3·00	∪45	5·45	∪67	7·63
∪18	3·50	45·8	5·50	69·4	8·00
∪21	3·72	∪49	5·83	73	8·50
25·8	4·00	∪51·4	6·00	76·8	9·00
∪26	4·04	∪52	6·10	80	9·50
∪32	4·44	∪55	6·38	∪83	10·00
∪33	4·50	∪56·5	6·50	85	10·30
39·5	5·00	∪60	6·90		

Arseniuretted Hydrogen.—This body, liquefied by Dumas and Soubeiran, did not solidify at the lowest temperature to which I could submit it, i. e. not at 166° below 0° Fahr. In the following table of the elasticity of its vapour the marked results are experimental, and the others interpolated:—

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
∪−75°	0·94	−30°	2·84	∪10°	6·24
−70	1·08	∪−23	3·32	∪20	7·39
∪−64	1·26	−20	3·51	30	8·66
−60	1·40	−10	4·30	∪32	8·95
∪−52	1·73	∪− 5	4·74	∪40	10·05
−50	1·80	∪ 0	5·21	∪50	11·56
−40	2·28	∪ 3	5·56	∪60	13·19
∪−36	2·50				

The following bodies would not freeze at the very low temperature of the carbonic acid bath *in vacuo* (−166° Fahr.):—Chlorine, ether, alcohol, sulphuret of carbon, caoutchoucine, camphine or rectified oil of turpentine. The alcohol, caoutchoucine, and camphine lost fluidity and thickened somewhat at −106°, and still more at the lower temperature of −166°. The alcohol then poured from side to side like an oil.

Dry yellow fluid nitrous acid when cooled below 0° loses the greater part of its colour, and then fuses into a white, crystalline, brittle and but slightly translucent substance, which fuses a little above 0° Fahr. The green and probably hydrated acid required a much lower temperature for its solidification, and then became a pale bluish solid. There were then evidently two bodies, the dry acid which froze out first, and then the hydrate, which requires at least −30° below 0° before it will solidify.

The following gases showed no signs of liquefaction when cooled by the carbonic acid bath *in vacuo*, even at the pressures expressed :—

	Atmospheres.
Hydrogen at	27
Oxygen at	27
Nitrogen at	50
Nitric oxide at	50
Carbonic oxide at	40
Coal gas	32

The difference in the facility of leakage was one reason of the difference in the pressure applied. I found it impossible, from this cause, to raise the pressure of hydrogen higher than twenty-seven atmospheres by an apparatus that was quite tight enough to confine nitrogen up to double that pressure.

M. Cagniard de la Tour has shown that at a certain temperature, a liquid, under sufficient pressure, becomes clear transparent vapour or gas, having the same bulk as the liquid. At this temperature, or one a little higher, it is not likely that any increase of pressure, except perhaps one exceedingly great, would convert the gas into a liquid. Now the temperature of 166° below 0°, low as it is, is probably *above* this point of temperature for hydrogen, and perhaps for nitrogen and oxygen, and then no compression without the conjoint application of a degree of cold below that we have as yet obtained, can be expected to take from them their gaseous state. Further, as ether assumes this state before the pressure of its vapour has acquired thirty-eight atmospheres, it is more than probable that gases which can resist the pressure of from twenty-seven to fifty atmospheres at a temperature of 166° below 0° could never appear as liquids, or be made to lose their gaseous state at common temperatures. They may probably be brought into the state of very condensed gases, but not liquefied.

Some very interesting experiments on the compression of gases have been made by M. G. Aimé*, in which oxygen, olefiant, nitric oxide, carbonic oxide, fluosilicon, hydrogen, and nitrogen gases were submitted to pressures, rising up to 220 atmospheres in the case of the two last; but this was in the depths of the sea where the results under pressure could not be examined. Several of them were diminished in bulk in a ratio far greater than the pressure put upon them; but both M. Cagniard de la Tour and M. Thilorier have shown that this is often the case whilst the substance retains the gaseous form. It is possible that olefiant gas and fluosilicon may have liquefied down below, but they have not yet been seen in the liquid state except in my own experiments, and in them not at temperatures above 40° Fahr. The results with oxygen are so unsteady and contradictory as to cause doubt in regard to those obtained with the other gases by the same process.

Thus, though as yet I have not condensed oxygen, hydrogen, or nitrogen, the ori-

* Annales de Chimie, 1843, viii. 275.

ginal objects of my pursuit, I have added six substances, usually gaseous, to the list of those that could previously be shown in the liquid state, and have reduced seven, including ammonia, nitrous oxide, and sulphuretted hydrogen, into the solid form. And though the numbers expressing tension of vapour cannot (because of the difficulties respecting the use of thermometers and the apparatus generally) be considered as exact, I am in hopes they will assist in developing some general law governing the vaporization of all bodies, and also in illustrating the physical state of gaseous bodies as they are presented to us under ordinary temperature and pressure.

Royal Institution,
Nov. 15, 1844.

Note.—*Additional remarks respecting the Condensation of Gases.*

By Michael Faraday, *Esq.*

Received February 20,—Read February 20, 1845.

Nitrous oxide.—Suspecting the presence on former occasions of nitrogen in the nitrous oxide, and mainly because of muriate in the nitrate of ammonia used, I prepared that salt in a pure state from nitric acid and carbonate of ammonia previously proved, by nitrate of silver, to be free from muriatic acid. After the nitrous oxide prepared from this salt had remained for some days in well-closed bottles in contact with a little water, I condensed it in the manner already described, and when condensed I allowed half the fluid to escape in vapour, that as much as possible of the less condensable portion might be carried off. In this way as much gas as would fill the capacity of the vessels twenty or thirty times or more was allowed to escape. Afterwards the following series of pressures was obtained:—

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
−125°	1·00	−70°	4·11	−15°	14·69
−120°	1·10	−65°	4·70	−10°	16·15
−115°	1·22	−60°	5·36	− 5°	17·70
−110°	1·37	−55°	6·09	0°	19·34
−105°	1·55	−50°	6·89	5°	21·07
−100°	1·77	−45°	7·76	10°	22·89
− 95°	2·03	−40°	8·71	15°	24·80
− 90°	2·34	−35°	9·74	20°	26·80
− 85°	2·70	−30°	10·85	25°	28·90
− 80°	3·11	−25°	12·04	30°	31·10
− 75°	3·58	−20°	13·32	35°	33·40

These numbers may all be taken as the results of experiments. Where the temperatures are not those actually observed, they are in almost all cases within a degree of it, and proportionate to the effects really observed. The departure of the real observations from the numbers given is very small. This table I consider as far more worthy of confidence than the former, and yet it is manifest that the curve is not consistent with the idea of a pure single substance, for the pressures at the lowest temperature are too high. I believe that there are still two bodies present, and that the more volatile, as before said, is condensable in the liquid of the less volatile; but I think there is a far smaller proportion of the more volatile (nitrogen, or whatever it may be) than in the former case.

Olefiant gas.—The olefiant gas condensed in the former experiment was prepared in the ordinary way, using excellent alcohol and sulphuric acid; then washed by agitation with about half its bulk of water, and finally left for three days over a thick mixture of lime and water with occasional agitation. In this way all the sulphurous and carbonic acids were removed, and I believe all the ether, except such minute portions as could not interfere with my results. In respect of the ether, I have since found that the process is satisfactory; for when I purposely added ether vapour to air, so as to increase its bulk by one-third, treatment like that above removed it, so as to leave the air of its original volume. There was yet a slight odour of ether left, but not so much as that conferred by adding one volume of the vapour of ether to 1200 or 1500 volumes of air. I find that when air is expanded $\frac{1}{4}$th or $\frac{1}{3}$rd more by the addition of the vapour of ether, washing first of all with about $\frac{1}{10}$th of its volume of water, then again with about as much water, and lastly with its volume of water, removes the ether to such a degree, that though a little smell may remain, the air is of its original volume.

As already stated, it is the presence of other and more volatile hydrocarbons than olefiant gas, which the tensions obtained seemed to indicate, both in the gas and the liquid resulting from its condensation. In a further search after these I discovered a property of olefiant gas which I am not aware is known (since I do not find it referred to in books), namely its ready solubility in strong alcohol, ether, oil of turpentine, and such like bodies*. Alcohol will take up two volumes of this gas; ether can absorb two volumes; oil of turpentine two volumes and a half; and olive oil one volume by agitation at common temperatures and pressure; consequently, when a vessel of olefiant gas is transferred to a bath of any of these liquids and agitated, absorption quickly takes place.

Examined in this way, I have found no specimen of olefiant gas that is entirely absorbed; a residue always remains, which, though I have not yet had time to examine it accurately, appears to be light carburetted hydrogen; and I have no doubt that this is the substance which has mainly interfered in my former results. This sub-

* Water, as Berzelius and others have pointed out, dissolves about $\frac{1}{4}$th its volume of olefiant gas, but I find that it also leaves an insoluble residue, which burns like light carburetted hydrogen.

stance appears to be produced in every stage of the preparation of olefiant gas. On taking six different portions of gas at different equal intervals, from first to last, during one process of preparation, after removing the sulphurous and carbonic acid and the ether as before described, then the following was the proportion per cent. of insoluble gas in the remainder when agitated with oil of turpentine, 10·5; 10; 10·1; 13·1; 28·3; 61·8. Whether carbonic oxide was present in any of these undissolved portions I cannot at present say.

In reference to the part dissolved, I wish as yet to guard myself from being supposed to assume that it is one uniform substance; there is indeed little doubt that the contrary is true; for whilst a volume of oil of turpentine introduced into twenty times its volume of olefiant gas cleared from ether and the acids, absorbs 2½ volumes of the gas, the same volume of fresh oil of turpentine brought into similar contact with abundance of the gas which remains when one-half has been removed by solution only dissolved 1·54 part, yet there was an abundant surplus of gas which would dissolve in fresh oil of turpentine at this latter rate. When two-thirds of a portion of fresh olefiant gas were removed by solution, the most soluble portion of that which remained required its bulk of fresh oil of turpentine to dissolve it. Hence at first one volume of camphine dissolved 2·50, but when the richer portion of the gas was removed, one volume dissolved 1·54 part; and when still more of the gas was taken away by solution, one volume of camphine dissolved only one volume of the gas. This can only be accounted for by the presence of various compounds in the soluble portion of the gas.

A portion of good olefiant gas was prepared, well-agitated with its bulk of water in close vessels, left over lime and water for three days, and then condensed as before. When much liquid was condensed, a considerable proportion was allowed to escape to sweep out the uncondensed atmosphere and the more condensable vapours; and then the following pressures were observed:—

Fahr.	Atmospheres.	Fahr.	Atmospheres.	Fahr.	Atmospheres.
−105	4·60	−65	8·30	−30	16·22
−100	4·82	−60	9·14	−25	17·75
− 95	5·10	−55	10·07	−20	19·38
− 90	5·44	−50	11·10	−15	21·11
− 85	5·84	−45	12·23	−10	22·94
− 80	6·32	−40	13·46	− 5	24·87
− 75	6·89	−35	14·79	0	26·90
− 70	7·55				

On examining the form of the curve given by these pressures, it is very evident that, as on former occasions, the pressures at low temperatures are too great to allow the condensed liquid to be considered as one uniform body, and the form of the curve at the higher pressures is quite enough to prove that no ether was present either in

this or the former fluids. On permitting the liquid in the tube to expand into gas, and treating 100 parts of that gas with oil of turpentine, eighty-nine parts were dissolved, and eleven parts remained insoluble. There can be no doubt that the presence of this latter substance, soluble as it is under pressure in the more condensable portions, is the cause of the irregularity of the curve, and the too high pressure at the lower temperatures.

The ethereal solution of olefiant gas being mixed with eight or nine times its volume of water, dissolved and gradually minute bubbles of gas appeared, the separation of which was hastened by a little heat. In this way about half the gas dissolved was re-obtained, and burnt like very rich olefiant gas. One volume of the alcoholic solution, with two volumes of water, gave very little appearance of separating gas. Even the application of heat did not at first cause the separation, but gradually about half the dissolved olefiant gas was liberated.

The separation of the dissolved gas by water, heat, or change of pressure from its solutions, will evidently supply means of procuring olefiant gas in a greater state of purity than heretofore; the power of forming these solutions will also very much assist in the correct analysis of mixtures of hydrocarbons. I find that light carburetted hydrogen is hardly sensibly soluble in alcohol or ether, and in oil of turpentine the proportion dissolved is not probably $\frac{1}{15}$th the volume of the fluid employed; but the further development of these points I must leave for the present.

Carbonic acid.—This liquid may be retained in glass tubes furnished with cemented caps, and closed by plugs or stop-cocks, as described, but it is important to remember the softening action on the cement which, being continued, at last reduces its strength below the necessary point. A tube of this kind was arranged on the 10th of January and left; on the 15th of February it exploded, not by any fracture of the tube, for that remained unbroken, but simply by throwing off the cap through a failure of the cement. Hence the cement joints should not be used for long experiments, but only for those enduring for a few days.

Oxygen.—Chlorate of potassa was melted and pulverized. Oxide of manganese was pulverized, heated red-hot for half an hour, mixed whilst hot with the chlorate, and the mixture put into a long strong glass generating tube with a cap cemented on, and this tube then attached to another with a gauge for condensation. The heat of a spirit lamp carefully applied produced the evolution of oxygen without any appearance of water, and the tubes, both hot and cold, sustained the force generated. In this manner the pressure of oxygen within the apparatus was raised as high as 58·5 atmospheres, whilst the temperature at the condensing place was reduced as low as −140° Fahr., but no condensation appeared. A little above this pressure the cement of two of the caps began to leak, and I could carry the observation no further with this apparatus.

From the former scanty and imperfect expressions of the elasticity of the vapour of the condensed gases, Dove was led to put forth a suggestion*, whether it might not ultimately appear that the same addition of heat (expressed in degrees of the thermometer) caused the same additional increase of expansive force for all gases or vapours in contact with their liquids, provided the observation began with the same pressure in all. Thus to obtain the difference between forty-four and fifty atmospheres of pressure, either with steam or nitrous oxide, nearly the same number of degrees of heat were required; to obtain the difference between twenty and twenty-five atmospheres, either with steam or muriatic acid, the same number were required. Such a law would of course make the rate of increasing expansive force the same for all bodies, and the curve laid down for steam would apply to every other vapour. This, however, does not appear to be the case. That the force of the vapour increases in a geometrical ratio for equal increments of heat is true for all bodies, but the ratio is not the same for all. As far as observations upon the following substances, namely, water, sulphurous acid, cyanogen, ammonia, arseniuretted hydrogen, sulphuretted hydrogen, muriatic acid, carbonic acid, olefiant gas, &c., justify any conclusion respecting a general law, it would appear that the more volatile a body is, the more rapidly does the force of its vapour increase by further addition of heat, commencing at a given point of pressure for all; thus for an increase of pressure from two to six atmospheres, the following number of degrees require to be added for the different bodies named: water 69°, sulphurous acid 63°, cyanogen 64°·5, ammonia 60°, arseniuretted hydrogen 54°, sulphuretted hydrogen 56°·5, muriatic acid 43°, carbonic acid 32°·5, nitrous oxide 30°; and though some of these numbers are not in the exact order, and in other cases, as of olefiant gas and nitrous oxide, the curves sometimes even cross each other, these circumstances are easily accounted for by the facts already stated of irregular composition and the inevitable errors of first results. There seems every reason therefore to expect that the increasing elasticity is directly as the volatility of the substance, and that by further and more correct observation of the forces, a general law may be deduced, by the aid of which, and only a single observation of the force of any vapour in contact with its fluid, its elasticity at any other temperature may be obtained.

Whether the same law may be expected to continue when the bodies approach near to the Cagniard de la Tour state is doubtful. That state comes on sooner in reference to the pressure required, according as the liquid is lighter and more expansible by heat and its vapour heavier, hence indeed the great reason for its facile assumption by ether. But though with ether, alcohol and water, that substance which is most volatile takes up this state with the lowest pressure, it does not follow that it should always be so; and in fact we know that ether takes up this state at a pressure between thirty-seven and thirty-eight atmospheres, whereas muriatic acid, nitrous oxide, carbonic acid and olefiant gas, which are far more volatile, sustain a higher pressure

* Poggendorff's Annalen, xxiii. 290; or Thomson on Heat and Electricity, p. 9.

than this without assuming that peculiar state, and whilst their vapours and liquids are still considerably different from each other. Now whether the curve which expresses the elastic force of the vapour of a given fluid for increasing temperatures continues undisturbed after that fluid has passed the CAGNIARD DE LA TOUR point or not is not known, and therefore it cannot well be anticipated whether the coming on of that state sooner or later with particular bodies will influence them in relation to the more general law referred to above.

The law already suggested gives great encouragement to the continuance of those efforts which are directed to the condensation of oxygen, hydrogen and nitrogen, by the attainment and application of lower temperatures than those yet applied. If to reduce carbonic acid from the pressure of two atmospheres to that of one, we require to abstract only about half the number of degrees that is necessary to produce the same effect with sulphurous acid, it is to be expected that a far less abstraction will suffice to produce the same effect with nitrogen or hydrogen, so that further diminution of temperature and improved apparatus for pressure, may very well be expected to give us these bodies in the liquid or solid state.

Royal Institution,
Feb. 19, 1845.